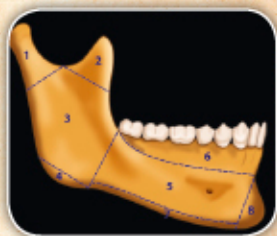
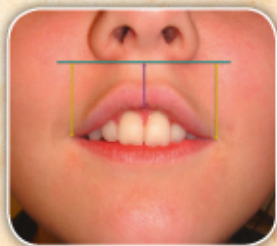
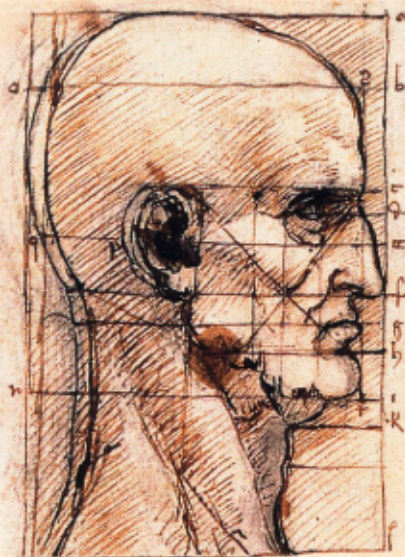
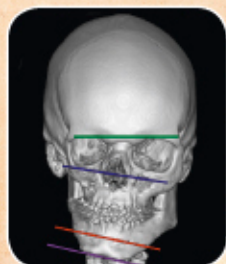


FARHAD B. NAINI

FACIAL AESTHETICS

CONCEPTS & CLINICAL DIAGNOSIS



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Facial Aesthetics

Concepts & Clinical Diagnosis



With the eyes of an artist and the mind of a scientist...

Facial Aesthetics

Concepts & Clinical Diagnosis

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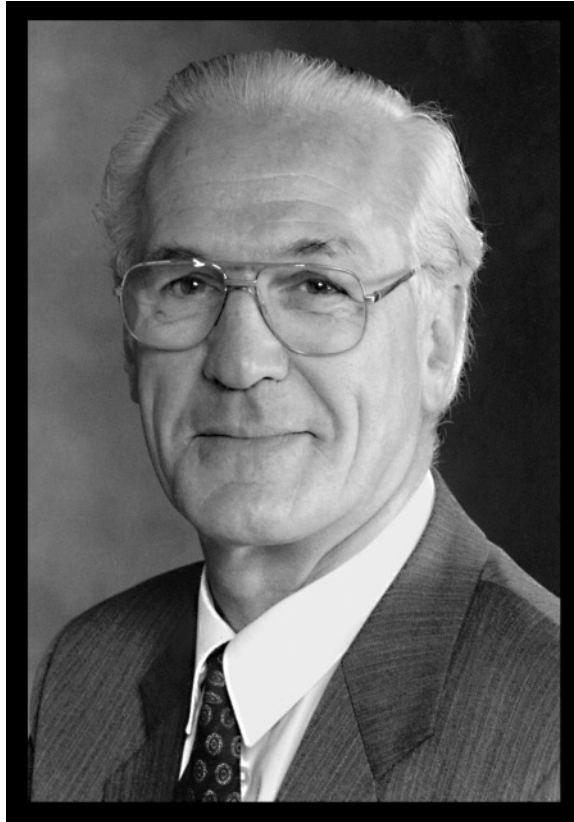
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To the memory of
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Pioneer of modern craniofacial
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Preface

‘Everything is in the face ...’

Cicero (106–43 BC), *De Oratore*, Volume III, 55 BC

Nowhere in medicine is the fusion of art and science more important than in the clinical assessment of facial aesthetics.



The Scales of Facial Aesthetics

The separation of art and science has been a relatively recent phenomenon in medicine. In fact, at the highest intellectual levels, the humanities and the sciences merge, forming a symbiotic relationship. Science and art are as closely bound together as the heart and the mind; the mind without the heart cannot survive, and the heart without the mind is of no use.

The greatest artists of the past were also the master scientists of their age. Much of modern scientific methodology has grown out of the notably enquiring minds and investigations of such individuals. The fusion of art and science made extensive progress in the Renaissance, with Leonardo da Vinci emerging as the notable example of the harmonic relationship between science and art. Leonardo did not consider art and science as separate entities, but felt that they were inextricably linked. It was his conviction that the artist had to employ scientific methodology and the scientist the tools and observational ability of the artist.

‘The human features and countenance, although composed of but some ten parts or little more, are so fashioned that among so many thousands of men there are no two in existence who cannot be distinguished from one another.’

Pliny the Elder (AD 23–79), *Natural History*, Volume VII

Recognition of the range of normal morphological features of the craniofacial complex is important. A mild or even moderate deviation of any facial parameter from the ‘norm’ is simply part of individual biological variability – it is what makes each face unique. However, severe deviations from the norm may warrant treatment, due to both a patient’s aesthetic concern, their want to look ‘normal’ and the often-associated functional problems.

‘Neither natural ability without instruction nor instruction without natural ability can make the perfect artist.’

Vitruvius (first century BC), *De Architectura* (‘On Architecture’), Chapter 1: The Education of the Architect

Throughout medicine, clinical diagnosis remains the most important step in the management of patients. Technical skill without diagnostic ability is fruitless. The modern fixation on techniques and technical modalities cannot afford to be at the cost of reduced emphasis on diagnostic ability. Just as a physician equipped with more and more drugs cannot treat a patient unless the original diagnosis is correct, a clinician involved in the management of facial deformities cannot provide the correct treatment unless the diagnostic process is logical and the diagnosis accurate.

The purpose of this book is to present and provide practical order to the encyclopaedic information available from the arts and the sciences in order to set the foundations of clinical diagnosis in facial aesthetics and the management of facial deformities. As such, the book is divided into two parts:

- **Part I – Concepts:** The background knowledge required for a well-informed clinician is covered in Chapters 1–4.

- **Part II – Clinical Diagnosis:** The ability and discipline to conduct a systematic (methodical), accurate and thorough clinical evaluation constitutes the most difficult step in the management of patients with facial deformities. Patient evaluation required for clinical diagnosis is covered in four sections, divided into Chapters 5–24.

The clinician should develop the ability to detect details that are not readily apparent to the untrained eye. The only way to master clinical evaluation is by judicious and continuous practice; analysing normal faces, beautiful faces, patients with dentofacial and craniofacial deformities, comparison of patients before and after treatment. If treatment results are good, why are they good? If the results are not as good as expected, why?

Only having mastered clinical diagnosis will the clinician be able to apply and develop the technical expertise and surgical finesse required to provide patients with the highest possible level of care.

A large, abstract blue graphic in the top right corner of the page, consisting of several overlapping, curved shapes that create a sense of depth and movement. The colors range from a light sky blue to a deeper cerulean.

Dedication

For my family:

My mother Nasrin, my father Bahram and my brother Jamshid – for your unconditional love, unwavering support and wisdom – words cannot express how much I love you.

My darling wife and soulmate Hengameh – you are quite simply the love of my life.

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My special thanks are due to the Librarians and staff of the Royal Library for their kindness in allowing me to select the illustrations from the incomparable collection of Leonardo da Vinci's drawings from The Royal Collection at Windsor Castle, by Gracious Permission of Her Majesty Queen Elizabeth II.

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My earlier education was shaped by a number of remarkable teachers, notably Mr Christopher Town, Mr Terence Robinson and Dr Mark Innes. I owe the foundation of my undergraduate training to Professor Tim F. Watson at Guy's Hospital – the superlative may be applied to him as a clinician, researcher and educator.

My interest in craniofacial anatomy and the developmental biology of the head and neck developed as an undergraduate student at Guy's Hospital, under the tutelage and guidance of Professors Martin Berry and Susan Standring – both truly inspirational teachers. I must also acknowledge Professor Chummy Sinnatamby and his team at the Royal College of Surgeons of England, whose teaching of surgical anatomy is unique and memorable.

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PART I CONCEPTS

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Chapter 1 Facial Beauty

‘Beauty itself doth of itself persuade
The eyes of men without an orator.’

William Shakespeare (1564–1616), *The Rape of Lucrece* (1594)¹

Definition of beauty and aesthetics

‘Beauty as we feel it is something indescribable:
what it is or what it means can never be said.’

George Santayana (1863–1952), *The Sense of Beauty* (1896)²

It is almost impossible to clearly and accurately define **beauty**. Definitions often do not and cannot elucidate the full significance of the concept of beauty. Beauty may be defined as ‘a combination of qualities that give pleasure to the senses or to the mind.’³ The *Oxford English Dictionary* defines beauty as:

‘A combination of qualities, such as shape, colour, or form, which pleases the aesthetic senses, especially the sight.’

The Renaissance artist and thinker **Leon Battista Alberti** (1404–72) defined beauty as:

‘The summation of the parts working together in such a way that nothing needs to be added, taken away or altered.’⁴

The various definitions of beauty and facial beauty all essentially describe the assemblage of graceful features that please the eye and mind of an observer, yet the definitions are philosophical,

debatable and non-specific. Three variables exist in the definitions of beauty:

- **The graceful features:** The human face is comprised of a number of ‘features,’ e.g. the eyes, nose, lips, etc., with a wide array of shapes, sizes, relative positions and colours.
- **Their assemblage:** Which components of which features and in which combinations result in a beautiful face?
- **The observer:** Does each observer see and sense the same beauty?

The number of variables makes it clear that the concept of beauty is difficult to explain with complete clarity. In *Dreams of a Final Theory: The Search for the Fundamental Laws of Nature* (1993), the Nobel prize-winning theoretical physicist Steven Weinberg eloquently writes:

‘I will not try to define beauty, any more than I would try to define love or fear. You do not define these things; you know them when you feel them.’⁵

Aesthetics is the study of beauty and, to a lesser extent, its opposite, the ugly. The eighteenth-century German philosopher **Alexander Baumgarten** (1714–62) established aesthetics as a distinct field of philosophy with the publication of his treatise *Aesthetica* (c. 1750) (Figure 1.1).⁶ Baumgarten re-coined the term ‘aesthetics’ to mean ‘taste’ or ‘sense’ of beauty, thereby inventing its modern usage; the term ‘aesthetics’ is derived from the Greek word for *sensory perception* (*aisthētikos*). Baumgarten defined aesthetics as ‘the science of sensual cognition.’⁶ In effect, Baumgarten separated the concept of beauty from its ancient link related to ‘goodness’. Baumgarten defined ‘taste’ as the ability

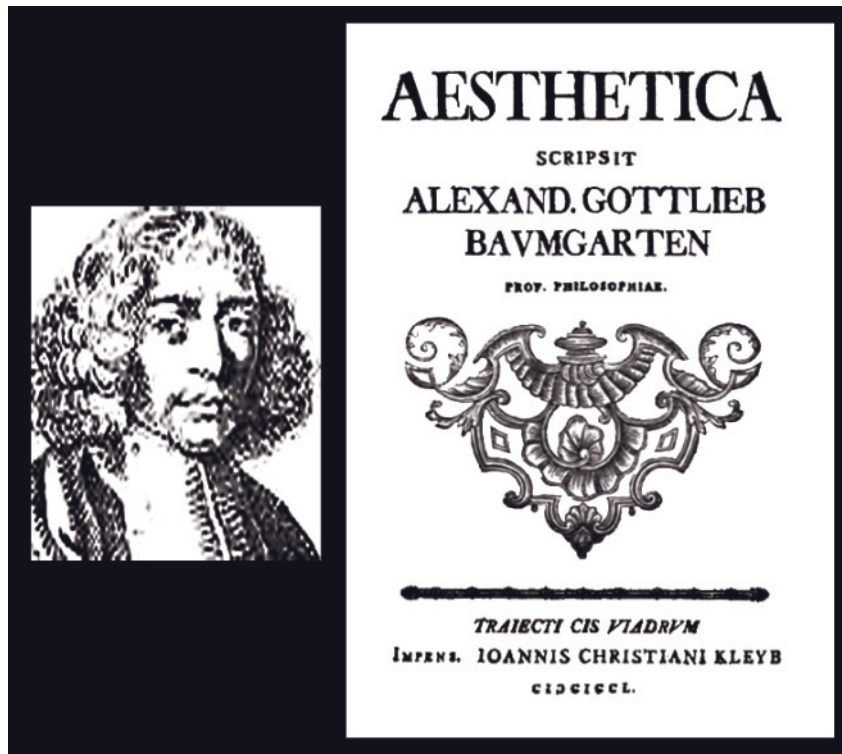


Figure 1.1 Alexander Gottlieb Baumgarten established aesthetics as a distinct field of philosophy with the publication of his treatise *Aesthetica* (c. 1750).

to judge according to the senses, instead of according to the intellect; such a judgement of taste is based on feelings of pleasure or displeasure.

Is beauty 'in the eye of the beholder'?

'Look in mine eye-balls, there thy beauty lies.'

William Shakespeare (1564–1616), *Venus and Adonis* (1593)⁷

A longstanding debate revolves round the question of the subjectivity-objectivity of beauty. Beauty may be considered a mystifying quality that some faces have, or may be 'in the eye of the beholder'. Does a face, which one person finds 'beautiful', appeal to another person in the same way? Is the 'beauty' of a face due to some *objective quality inherent in the face* or is it *subjectively determined by each individual* with their sensory enjoyment depending on their own ideas, feelings and judgements, which themselves have a direct relation to sensory enjoyment?

The idea that one individual's aesthetic sensibilities may differ from another's has a long tradition. **Plato** (428–348 BC) alluded to this concept in his *Symposium*, where he described 'Beholding beauty with the eye of the mind'.⁸ In the third century BC, the Greek poet **Theocritus** wrote: 'Beauty is not judged objectively, but according to the beholder's estimation' (*The Idylls*).⁹ **Shakespeare** (Figure 1.2) reiterated this view in *Love's Labour's*

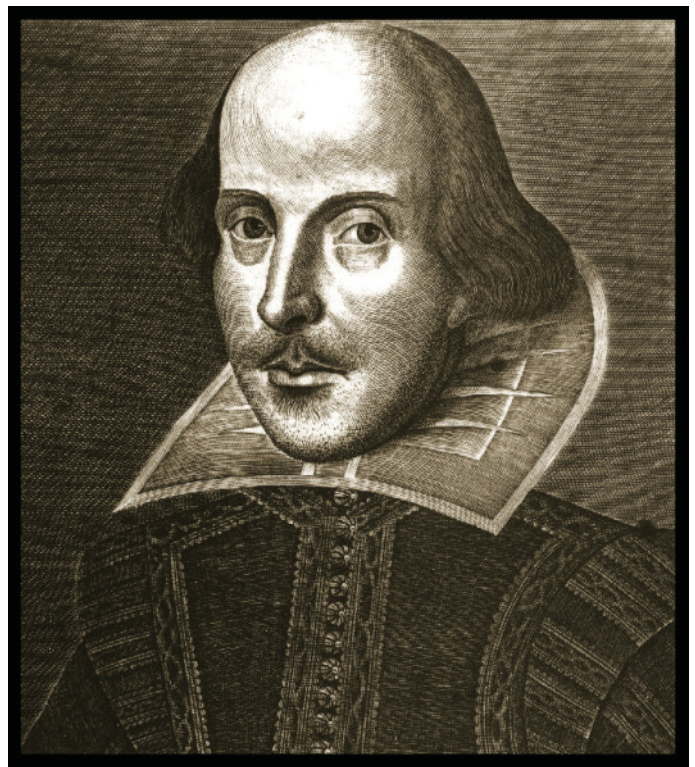


Figure 1.2 William Shakespeare – this copper-engraved image from the title page of the First Folio (1623) was made by the young English engraver Martin Droeshout probably from another drawing or painting now lost; it is the only reasonably authentic portrait of the Great Bard of Avon.



Figure 1.3 Francis Hutcheson.

Lost (1595), saying, 'Beauty is bought by judgement of the eye'.¹⁰ In his *Essays, Literary, Moral and Political* (1742) the Scottish philosopher **David Hume** wrote: 'Beauty, properly speaking, lies ... in the sentiment or taste of the reader'.¹¹ In *Jane Eyre* (1847) **Charlotte Brontë** wrote: 'Most true is it that 'beauty is in the eye of the gazer'.¹² Yet the idea that beauty is according to the observer's estimation became an adage when the writer **Margaret Wolfe Hungerford** in *Molly Bawn* (1878) famously coined the expression: 'Beauty is in the eye of the beholder'.¹³ In *The Prince of India* (1893), the novelist Lew Wallace repeated the adage as: 'Beauty is altogether in the eye of the beholder'.¹⁴

The question to consider is one that remains difficult to answer: Is the origin of the human perception of facial beauty dependent on each individual's own sense perception, or is this 'sense' common to all men and women? The above quotations, and their respective philosophical ideology, assume that the 'sense' is subjective to each individual. However, the eighteenth-century philosopher **Francis Hutcheson** (1694–1746) (Figure 1.3) said:

'Aesthetic judgements are perceptual and take their authority from a sense that is common to all who make them,'¹⁵

and he went on to say that

'The origin of our perceptions of beauty and harmony is justly called a "sense" because it involves no intellectual element, no reflection on principles and causes.'¹⁵

Therefore, if a beautiful face 'pleases universally' then some part of our 'sense' perception must be common to all men and women. After all, when we describe a face as beautiful, we do not merely mean that it pleases us. We are describing the face, not our judgement. We will often point to features of the face to back up our statement. A paradox therefore emerges. Obviously one cannot make a judgement regarding the beauty of a face one has never encountered. Therefore, facial beauty is related to some quality of the observed face, which may be 'universally' accepted. However, each individual's own ideas and feelings, like a conditioned response, also have a direct relationship to their judgement, hence the difference in the extent of rating a face as beautiful depending on the 'eye of the beholder'.³

It is important to bear in mind that any theory that cannot be directly and physically tested remains a philosophy, not a science. Therefore, the answer to the objectivity-subjectivity debate of facial beauty remains unanswered. *Perhaps beauty as a concept can be perceived but not fully explained.* This debate will no doubt continue.

Note

There is a plethora of evidence in the psychology literature which negates the statement that 'beauty is in the eye of the beholder' and supports the view that judgements of attractiveness are universal.¹⁶ Yet, most individuals will still admit that judgements of attractiveness differ. There is perhaps an explanation that may have been overlooked: different individuals will find different types of face 'very attractive', e.g. one individual may find a certain actor to be extremely beautiful whereas another may find them rather 'average'. The point is that neither will find the actor 'deformed'. It is only with faces within normal limits that arguments occur as to the level of attractiveness, and such judgements may often also be affected by factors other than beauty, e.g. the actor's talent or charisma. In other words, for faces with features that are 'within normal limits', beauty may be, to some extent, 'in the eye of the beholder'. Yet, if a patient with a facial deformity is observed, almost all individuals will agree that the face is deformed and not *physically* beautiful, i.e. *where deformity is concerned, beauty is no longer in the eye of the beholder.*

The enigma of facial beauty

Why is one face seen as beautiful and another as unattractive?

What guides and validates our judgement?

'Some day, I doubt not, we shall arrive at an understanding of the evolution of the aesthetic faculty; but all the understanding in the world will neither increase nor diminish the force of the intuition that *this* is beautiful and *that* is ugly.' [emphasis added]

Thomas Henry Huxley (1825–95) *Evolution and Ethics* (1893)¹⁷

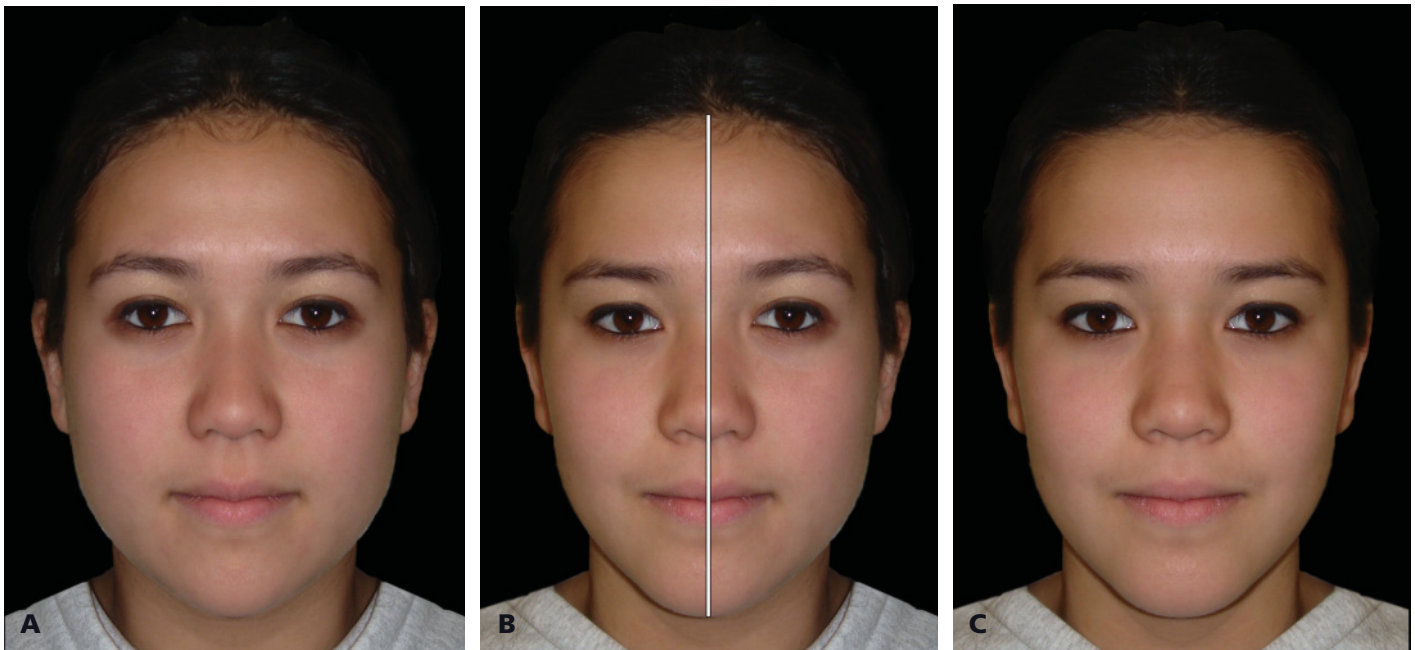


Figure 1.4 (A) Constructed composite image, in which the subject's left facial hemisphere has been mirrored on the right to create a symmetrical image. (B) Original true image. (C) Constructed composite image, in which the subject's right facial hemisphere has been mirrored on the left to create a symmetrical image. This technique illustrates the difference in the two sides of the face and that mild facial asymmetry is essentially normal.

The 'intuition' to which the British biologist Huxley is referring is the human ability to understand something *instinctively*; a thing that one knows from instinctive feeling, without the need for conscious reasoning. It is therefore possible that the human perception of beauty and the preference for one face over another is intuitive, for which there is no one clear explanation.

There are a variety of qualities and characteristics of a human face, which may be responsible for it being perceived as beautiful. These include 'ideal' proportions, bilateral symmetry, averageness, youthfulness and sexual dimorphism. Hereditary factors and cultural influences also play an important part. Any or all may have an effect on the human conception of the beautiful, but none fully explains *why* one face is seen as beautiful and another as unattractive. The true answer seems destined to remain an enigma.

Nevertheless, a number of explanations and hypotheses have been used in the attempt to explain why a face may be perceived as beautiful and another as unattractive:

'Ideal' proportions

The concept that 'ideal' proportions are the secret of beauty is perhaps the oldest idea regarding the nature of beauty. This subject will be discussed in detail in Chapter 2.

Symmetry

Facial symmetry also seems to be an important aspect of facial beauty, although mild asymmetry is essentially normal.¹⁸ In fact, image manipulation techniques used to create perfectly

symmetrical facial images of the same individual have found the original to be more attractive than the created perfectly symmetrical image (Figure 1.4), i.e. 'normal' asymmetry is preferred to perfect bilateral facial symmetry.¹⁹ Rhodes et al.²⁰ found that symmetry was an important factor in facial attractiveness, but 'averageness' appears to be more important. Rubenstein et al.¹⁶ concurred that no matter how symmetrical a face, 'averageness is the only characteristic discovered to date which is both necessary and sufficient to ensure facial attractiveness ... without a facial configuration close to the average of the population, a face will not be attractive.'

Averageness

Studies in the late 1800s by Sir Francis Galton (1822–1911) (Figure 1.5), cousin of Charles Darwin, accidentally found evidence to support what came to be known as the **averageness hypothesis** of facial beauty.²¹ Galton was in fact trying to find *typical faces*, e.g. the typical 'criminal face'. He created composite faces by overlaying multiple images of prisoners and criminals or a variety of other subjects onto a photographic plate. Not only was Galton's original theory of 'typical faces' incorrect, but he found that the composite faces became more attractive than any of the individual faces (Figure 1.6). Further research has verified that composite facial photographs gain higher attractiveness ratings than their individual facial photographs.²² However, Perrett et al.²³ have shown that attractive composite faces were made more attractive by exaggerating the shape differences from the sample mean. Therefore, an average face shape is attractive but may not be optimally attractive.

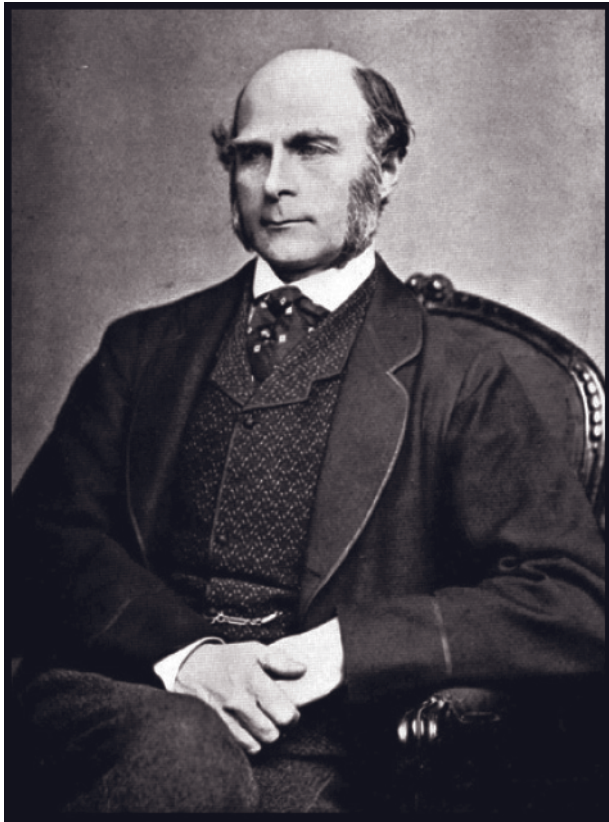


Figure 1.5 Sir Francis Galton.

Note

The term *koinophilia* ('love of the average'), derived from the Greek *koinos*, ('common' or 'average'), and *philos* ('love'), means when seeking a mate, sexual creatures prefer that mate to have a preponderance of average or common physical features, i.e. not to exhibit any unusual or peculiar features. The argument is that *natural selection* leads to beneficial physical features becoming increasingly more common with each generation, while the disadvantageous features become increasingly rare. Thus, sexual creatures wishing to mate with a 'fit' partner (in evolutionary terms, 'fit' means 'best able to adapt to the environment', and thereby have a better chance of bearing healthy offspring), would be expected to avoid individuals with unusual features, while being attracted to those displaying 'average' features. This *mating strategy* was first referred to as *koinophilia* by the biologist Johan Koeslag.²⁴ In humans, this concept may be linked to the 'averageness hypothesis'.^{19,22}

The term 'averageness' implies proximity to the population mean, i.e. the use of **normative data** from population samples are often used by orthodontists and facial aesthetic surgeons, in the form of cephalometric and anthropometric data, for diagnosis and treatment planning.

Facial neoteny

The term **neoteny** refers to the retention of juvenile features in the adult, alternatively termed **paedomorphosis**. The retention of neotenous *facial* features in adult humans is also termed **baby-faceness**. Child-like facial features, such as relatively larger eyes, small nose, full lips and a round face have been found to correlate with attractiveness, particularly for women. This may be due to the natural human tendency to nurture a baby.²⁵ Nevertheless, there is also evidence that women find a combination of masculine and babyface (more feminine) features in men attractive, and that their preference for more masculine features increases during the menstruation phase most likely to result in successful conception.²⁶

Sexual dimorphism (secondary sexual characteristics)

Male and female faces diverge at puberty.²⁷ In males, testosterone stimulates the growth of the jaws, cheekbones, brow ridges and facial hair. In females, growth of these regions is inhibited by oestrogen, which may also increase lip size.²⁸ As sexual dimorphism increases at puberty, sexually dimorphic traits signal sexual maturity and reproductive potential.²⁷ Gillian Rhodes, one of the leading researchers in the field of psychology in relation to facial attractiveness, explains that current evidence suggests that femininity is attractive in female faces and is preferred to averageness; masculinity is also attractive in male faces, although the effect is smaller than for female faces. She concludes that the 'evolutionary psychology of facial attractiveness is just beginning!'²⁷

Heredity

The human perception of facial beauty may have its foundation in our heredity, environment or perhaps both. Langlois et al.²⁹ found that infants as young as 3 months of age have the ability to distinguish between attractive and unattractive faces, showing signs of preference for the former. It is unlikely that by 3 months of age an infant will have been subjected to or responded to any cultural or environmental influences, therefore this is evidence to support a genetic theory. The evolutionary basis is that facial beauty, including facial symmetry and secondary sexual characteristics, is a requirement for sexual selection, leading to improved chances for successful reproduction.³⁰

Cultural influences on the perception of facial beauty

'Ask a toad what is beauty? ... he will answer that it is a female with two great round eyes coming out of her little head, a large flat mouth, a yellow belly and a brown back.'

Voltaire (1694–1778), 'Beauty' (1764)³¹

The physician **Sinuhe** (c. twentieth century BC) informs us that in ancient Egypt women shaved their heads as a sign of



Figure 1.6 (A and B) Galton created composite faces by overlaying multiple images of groups of individuals onto a photographic plate in the attempt to find 'typical faces'. Not only was Galton's original theory of 'typical faces' incorrect, but he found that the composite faces became more attractive than any of the individual faces.

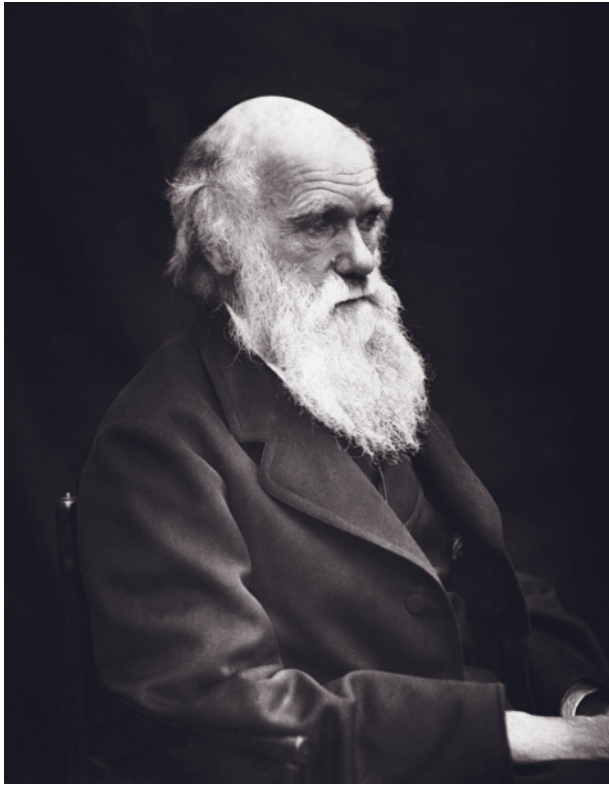


Figure 1.7 Charles Darwin age 65 (c. 1874).

beauty, and men found the bare female head ‘most beautiful’. Yet, when he describes his beloved Mina, he recounts her ‘long, beautiful flowing hair’.³² In seventeenth-century Europe, particularly France, iodine was removed from the female diet in order for women to develop the ‘goitre neck’ appearance, then deemed a mark of attractiveness. The Mentawai tribe of Indonesia sharpen their anterior teeth to look like fangs using metal instruments such as chisels; within their culture this is perceived as a sign of beauty. In *The Descent of Man* (1871), the English naturalist **Charles Darwin** (1809–82) (Figure 1.7) observed and described large cultural differences in the beautification practices of peoples around the world.³³ There are many such examples of cultural factors, which undoubtedly have some considerable influence on our perception of beauty.

Martin³⁴ found that both white and black American males preferred black female faces with Caucasian features, whereas black African men showed a preference for black female faces with Negroid features. This lends evidence to support environmental/cultural reasons for the human perception of facial beauty. However, Perrett et al.³⁵ found that both Caucasian and Japanese men and women ranked female faces as most attractive when youthful facial features, such as large eyes, high cheekbones and a narrow jaw were evident. Aesthetic judgements therefore seemed to be similar across different cultural backgrounds. A meta-analysis undertaken by Langlois et al.³⁶ seems to confirm that there is cross-cultural agreement regarding facial attractiveness. However, the influence of an international media cannot be discounted.

Note

The significance of cultural influences and the pressures of conforming to societal ‘standards’ cannot be underestimated. Individuals have worn prescription spectacles in order to improve eyesight for many years. Initial public opinion was rather unflattering, which led the US critic and humorist Dorothy Parker to write (in 1926), albeit in jest, ‘Men seldom make passes, at girls who wear glasses.’ However, the era of modern ‘designer’ glasses has changed the image of the spectacle wearer. Conversely, hearing aids are still predominantly anathema to most individuals. The difference between the acceptance of glasses to improve vision and hearing aids to improve hearing is a prime example of cultural and societal influences on public perception.

It is likely that there is simply no one answer to why a face is perceived as beautiful or unattractive. Beauty cannot be explained by any single principle. The human perception of what constitutes facial beauty seems to be **multifactorial**, with genetic and environmental/cultural foundations. In *An Essay on Criticism* (1711)³⁷ Alexander Pope provides an explanation:

‘In wit, as Nature, what affects our hearts
Is not th’ exactness of peculiar parts;
Tis not a lip, or eye, we beauty call,
But the joint force and full result of all.
Thus when we view some well-proportion’d dome
... No single parts unequally surprise,
All comes united to th’ admiring eyes.’

Alexander Pope (1688–1744)

It is the **joint force** so eloquently described by the English poet Pope that is not fully understood – thus remains the enigma of facial beauty.

Facial beauty: historical and philosophical perspectives

Throughout history, each age seems to have provided somewhat different explanations for the concept of human beauty and its proposed merits. The opinions of some individuals have echoed one another, whereas others have vehemently disagreed.

Plato (429–347 BC) (Figure 1.8) described beauty as goodness, but felt that physical beauty was inferior to spiritual beauty, i.e. he described physical and metaphysical beauty (*Symposium*).⁸ In *Phaedo*, Plato informs us that **Socrates** (469–399 BC) (Figure 1.9) felt that the human body and physical beauty was an ‘impediment ... distracting us from getting a glimpse of the truth’, and that the beauty of the soul was far superior.³⁸ Socrates advises: ‘let us seek the *true* beauty, not asking whether a face is beautiful ... for such things are always in flux’; he continues: ‘grant that I may become beautiful *within*’.³⁸ The ideas of Socrates proved unpopular, to say the least, with the Greek masses’ love of physical beauty.

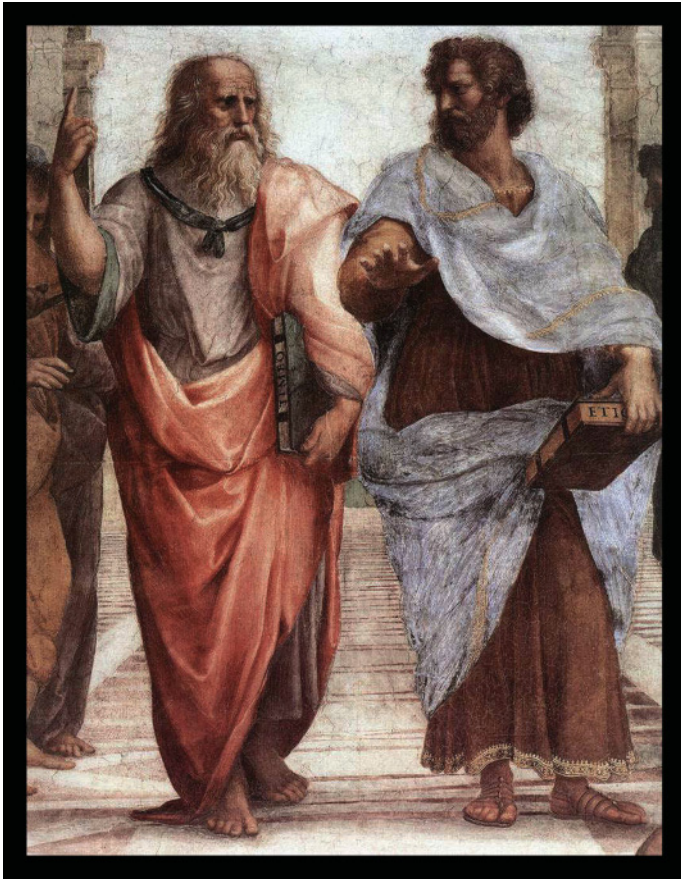


Figure 1.8 Plato and Aristotle. (Detail, The School of Athens c. 1509, Raphael; Stanza della Segnatura, Rome.)

Aristotle (384–322 BC) did not develop Plato's theory of 'beauty as goodness'. In fact, he distinguished between them, for 'goodness implied conduct as its subject, whereas beauty is found in motionless objects'. In his *Metaphysics*, Aristotle gave the following definition of beauty: 'The chief forms of beauty are order and symmetry and definiteness'; this is the idea of *beauty as proportion*.³⁹ Aristotle felt that beauty was a purely physical phenomenon and emphasized proportionality as the basis of human beauty, i.e. he denied the existence of metaphysical beauty. In his *Poetics*, Aristotle defined beauty as 'that which is desirable for its own sake and also worthy of praise'.⁴⁰ For the Greeks the concept of physical beauty was linked to their Gods, i.e. 'ideal' proportions and symmetry provided physical beauty to man, but this 'beauty' brought man closer to resembling the Gods.

Saint Thomas Aquinas (1225–74) separated physical and metaphysical beauty, but believed that both existed (*Summa Theologiae*):⁴¹

'Beauty of body consists in shapely limbs and features ...
beauty of spirit consists in conversations and actions that
are well-formed and suffused with intelligence.'

Aquinas believed spiritual beauty to be of a far 'higher order' than physical beauty. Despite Aquinas clearly separating spiritual and physical beauty, to the unenlightened medieval minds physical beauty and morality were inextricably linked, i.e. physical beauty was thought to be linked to goodness and physical ugliness to moral degradation.

The separation of the concept of beauty into a secular, non-spiritual, 'earthly' concept began with the **Renaissance** in the fourteenth to sixteenth centuries. The highly significant



Figure 1.9 The Death of Socrates. (1787, Jacques-Louis David, Metropolitan Museum of Art, New York.)



Figure 1.10 Michel de Montaigne (portrait c. 1590, artist unknown).

contributions of **Leon Battista Alberti**, **Leonardo da Vinci** and **Albrecht Dürer** to the understanding of beauty in art is discussed in detail in Chapter 2.

The writer **Michel de Montaigne** (1533–92) (Figure 1.10) and one of the most significant figures of the European intellectual movement of the seventeenth and eighteenth centuries known as the **Enlightenment**, the philosopher **Voltaire** (1694–1778) (Figure 1.11), described human beauty as *culturally determined*, with no objective existence, i.e. beauty is in the ‘culture’ of the beholder. Montaigne wrote of beauty:

‘We imagine its form to suit our fancy. ... In Peru, the biggest ears are the fairest, and they stretch them artificially. ... Elsewhere there are nations that blacken their teeth with great care, and scorn to see white teeth.’⁴²

David Hume (1711–76) (Figure 1.12) felt that beauty was not only culturally determined but also *individually subjective*, i.e. the idea that ‘beauty is in the eye of the beholder’. In his essay *Of the Standard of Taste* (1757), Hume wrote:⁴³

‘Beauty is no quality in things themselves: It exists merely in the mind which contemplates them; and each mind perceives a different beauty. One person may even perceive deformity, where another is sensible of beauty; and every individual ought to acquiesce in his own sentiment, without pretending to regulate those of others.’

Hume felt that beauty was a *socially constructed phenomenon*. In *The Sceptic* he wrote:⁴⁴

‘Beauty is not a quality of the circle ... it is only the effect, which that figure produces upon a mind, whose particular fabric or structure renders it susceptible of such sentiments.’

In *A Treatise on Human Nature* (1738) Hume wrote:⁴⁵



Figure 1.11 Voltaire.

‘Beauty is such an order and construction of parts, as ... to give a pleasure and satisfaction to the soul. This is the distinguishing character of beauty, and forms all the difference betwixt it and deformity, whose natural tendency is to produce uneasiness. Pleasure and pain, therefore, are not only necessary attendants of beauty and deformity, but constitute their very essence.’

Immanuel Kant (1724–1804) (Figure 1.13), in his *Critique of Judgement* (1790), rejected Hume and returned to Plato: ‘The beautiful is the symbol of the morally good.’⁴⁶ Tolstoy, in *The Kreutzer Sonata* (1890), opposed Kant, writing: ‘It is amazing how complete is the delusion that beauty is goodness.’⁴⁷ Another view expressed by Kant was that ‘the beautiful is that which pleases universally without a concept.’⁴⁸ **Friedrich Schiller** (1759–1805) (Figure 1.14) was a follower of Kant; he felt that beauty provided ‘pleasure without practical advantage.’⁴⁸ Philosophers and their opinions continued to wax and wane.

In *The Descent of Man* (1871) **Charles Darwin** described the cultural deviations in the standards of human beauty, writing:³³



Figure 1.12 David Hume.



Figure 1.14 Friedrich Schiller.



Figure 1.13 Immanuel Kant.

‘It is certainly not true that there is in the mind of man any universal standard of beauty with respect to the human body.’

Darwin believed that the perception of beauty is a feeling natural to man and to animals, and consequently to the ancestors of man. He also felt that beauty had an array of diverse conceptions and could not be easily explained. The evolutionary basis is that facial beauty makes a particularly significant contribution to sexual selection, leading to improved opportunity for reproduction.

In the nineteenth century, the American writer and thinker **Ralph Waldo Emerson** (1803–82) (Figure 1.15) wrote two essays entitled ‘Beauty’, in *Nature* (1836)⁴⁹ and in *The Conduct of Life* (1860).⁵⁰ In the former essay, Emerson explains that true beauty is inherent in Nature and the ‘simple perception of natural forms is a delight’. Yet he feels that the appreciation of such beauty requires ‘virtue’ and ‘intellect’ on the part of the observer. He writes: ‘No reason can be asked or given why the soul seeks beauty. Beauty, in its largest and profoundest sense, is one expression of the universe.’⁴⁹ In the latter essay, Emerson writes: ‘Beauty is the form under which the intellect prefers to study the world. All privilege is that of beauty; for there are many beauties; as, of general nature, of the human face and form, of manners, of brain, or method, moral beauty, or beauty of the soul’. In terms of physical beauty, he writes: ‘Any fixedness, heaping, or concentration on one feature – a long nose, a sharp chin, a hump-back – is the reverse of the flowing, and therefore deformed.’⁵⁰



Figure 1.15 Ralph Waldo Emerson.

In the twentieth century, in a published lecture entitled *Truth and Beauty* (1987), the distinguished Indian-born American astrophysicist and Nobel laureate **Subrahmanyan Chandrasekhar** (1910–95) explained that the quest of the arts and sciences is after ‘the same elusive quality: beauty.’⁵¹ He went on to define beauty as ‘that to which the human mind responds at its deepest and most profound.’⁵¹

Facial beauty: scientific perspectives

The scientific studies of the possible proposed explanations for facial beauty in terms of ‘ideal’ proportions, bilateral symmetry, averageness, babyfacedness and sexual dimorphism have been described above. The other area of scientific research in the understanding of facial beauty is termed **facial attractiveness research**, i.e. the scientific study of facial beauty and physical attractiveness. The purpose of such research is to find quantifiable evidence for the attractiveness of various facial parameters using contemporary layperson and patient population survey preferences rather than subjective interpretations or observations made by artists or clinicians. The results of such studies are, where available, presented throughout Part 2 of this book.

It is, however, important to know that the first scientific study of attractiveness was undertaken in England by the artist **William Hogarth** (1697–1764) (Figure 1.16), published in a work entitled *The Analysis of Beauty* (1753) (Figure 1.17).⁵² Hogarth drew the image of a woman’s corset, and then proceeded to create variations of the same image while altering a certain aspect of the corset in each image (Figure 1.18). He subsequently invited members of the public to choose their favourite image. The

Image not available in the electronic edition

Figure 1.16 William Hogarth’s *Painter and his Pug*; Hogarth has drawn his own image on an oval canvas, which appears propped up on volumes by Shakespeare, Swift and Milton. Careful examination of this self-portrait reveals that he has drawn his ‘S’ shaped ‘serpentine line’ on his palette, on which reads ‘The LINE of BEAUTY And GRACE – W.H.’ (1745, Tate Gallery, London). (With kind permission of the Tate Gallery, © Tate, London 2010.)

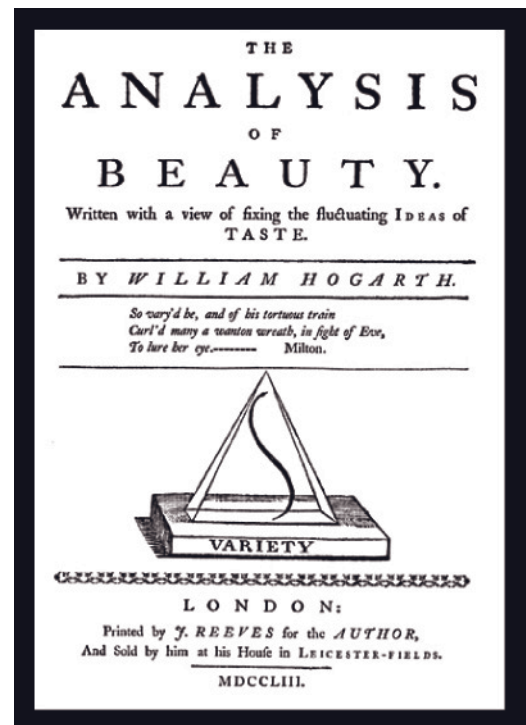


Figure 1.17 Hogarth’s *The Analysis of Beauty* (1753) (book cover).

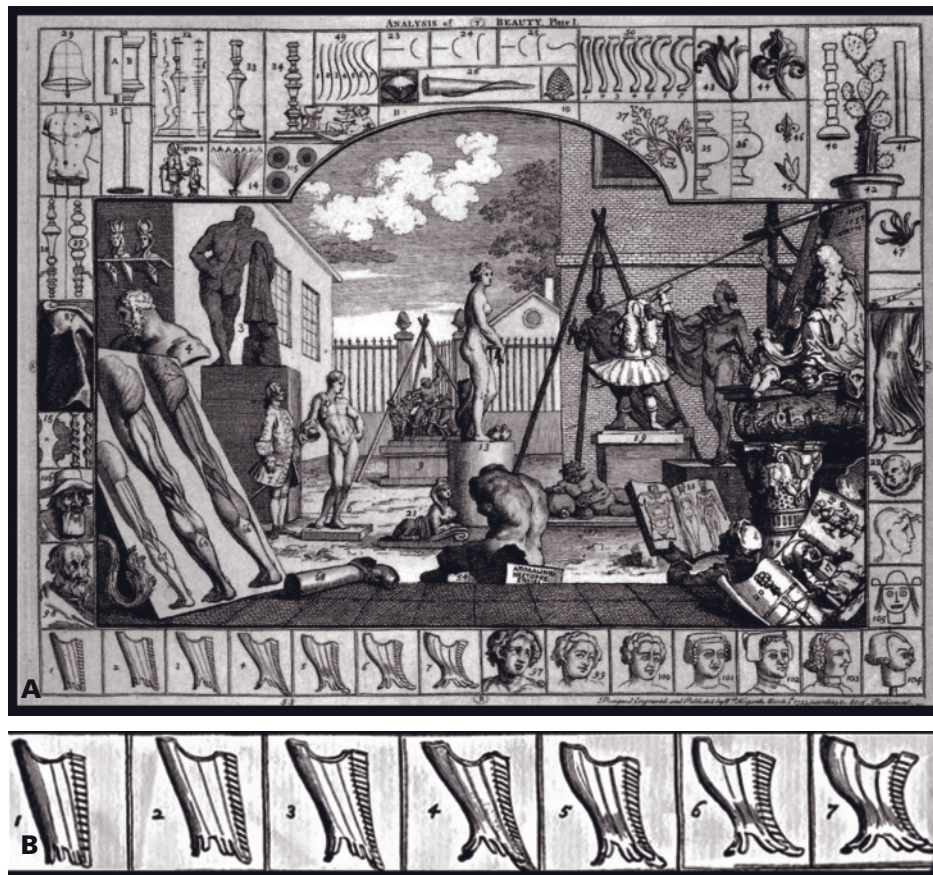


Figure 1.18 (A) Plate I from Hogarth's *The Analysis of Beauty* (1753). (B) Hogarth drew the image of a woman's corset, and then proceeded to create variations of the same image while altering a certain aspect of the corset in each image.

experiment was repeated using images of various objects (Figure 1.19). The originality of the experiment was that each set of images varied only in one respect and the variation was graded. Hogarth felt that this would allow him to know *why* one image was preferred to another. Hogarth's conclusion was that the most beautiful images were composed of *gently curving lines*. This led to Hogarth's concept of the **Line of Beauty**, a term used to describe an **S-shaped curved line**, or **serpentine line**, appearing within an object, as the boundary line of an object, or as a virtual boundary line formed by the composition of several objects (Figure 1.20). According to this theory, S-shaped curved lines signify liveliness and activity and excite the attention of the observer as contrasted with straight lines, parallel lines or right-angled intersecting lines, which signify inanimate, unattractive objects.

The idea that gently curving lines are important in beauty was not new; the concept runs through much of the poetry of the fourteenth century Persian poet-scholar **Hafez of Shiraz**. It is also clear that the serpentine line cannot be the only explanation of beauty, as was quickly pointed out by Hogarth's critic, the actor and playwright David Garrick (1717–79). Garrick explained that a shape that is attractive in one object may be rather unattractive in another, e.g. a gentle curve on the side of a vase is not

so attractive in a protruding belly! There is simply no one factor that creates beauty. Yet the experimental method chosen by Hogarth seems to be original, perhaps making him the 'father' of the modern attractiveness research design.

Importance of facial beauty

‘The gift of beauty not lightly to be thrown away,
that glorious gift which none can bestow save the
gods alone.’

Homer (eighth century BC), *Iliad*⁵³

The significance of facial beauty is immense, with psychological, sociological, philosophical, moral and scientific conceptions, often intertwined. Beauty is a *multidimensional concept* that undoubtedly has a strong influence on human life. In Western literature beauty has been described as everything from a ‘social necessity’ to a ‘gift from God’ (Aristotle).⁵⁴ The poet John Milton refers to the ‘strange power’ of beauty, describing beauty as ‘Nature’s brag’.⁵⁵ The French philosopher Blaise Pascal commented, ‘Cleopatra’s nose, had it been shorter, the whole face of the world would have been changed!’⁵⁶ From Homer’s Helen of Troy, who the poet Christopher Marlowe described as having the



Figure 1.19 Plate II from Hogarth's *The Analysis of Beauty* (1753).

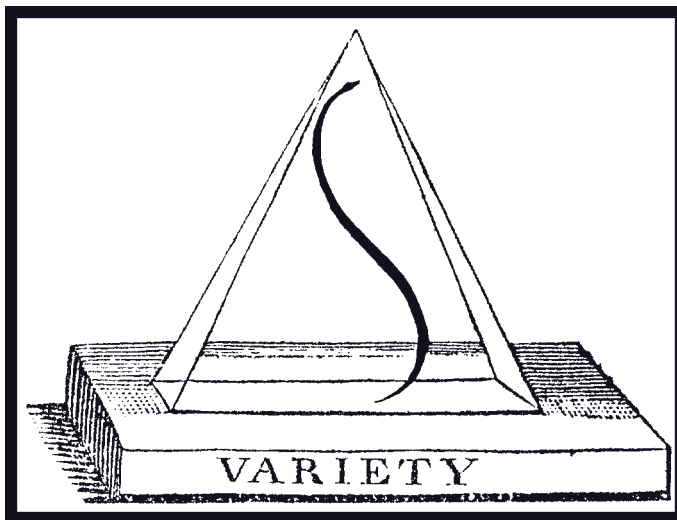


Figure 1.20 Hogarth's serpentine line.

'face that launched a thousand ships,'⁵⁷ to Queen Nefertiti, whose name literally means the 'Beautiful One' (Figure 1.21), to modern-day models and actors, facial beauty has perhaps always been the most valued aspect of human beauty.

Facial beauty is an important factor in an individual's self-image and in relation to outsiders' perceptions.

Self-image and negative self-perception

A person's own perception of their facial appearance and any associated deformity is of great importance.⁵⁸ Of course, there is



Figure 1.21 Queen Nefertiti – unfinished head. (Egyptian Museum, Cairo.)

considerable individual variation in people's abilities to adapt to their facial deformity, whatever the severity. Some individuals remain comparatively unaffected, while others may have significant difficulties, which affect their quality of life.



Figure 1.22 Arthur Schopenhauer.

Outsiders' perceptions

In *The Wisdom of Life*, the philosopher **Arthur Schopenhauer** (1788–1860) (Figure 1.22) writes:

'Beauty is partly an affair of health. It may be reckoned as a personal advantage; though it does not, properly speaking, contribute directly to happiness. It does so indirectly, by impressing other people; and it is no unimportant advantage, even in man. *Beauty is an open letter of recommendation*, predisposing the heart to favour the person who presents it.'⁵⁹ [emphasis added]

The effects of outsiders' perceptions may be categorized as follows:

'Social disability'

It has been argued that facial deformity may be a 'social disability', as it impacts not only on the individual affected, but is also noticed by and reacted to by others.⁶⁰ Attractive children tend to be perceived more positively by their parents,⁶¹ by teachers who perceive more attractive children as being more intelligent,⁶² and in professional life where less attractive adults are perceived as having fewer qualifications and less potential for employment success.⁶³ Although an individual's facial appearance contributes to the opinions other people form of them, obviously these opinions may well change as interpersonal relationships form. Nevertheless, an individual's first impression on others may well affect their own self-esteem and quality of life.⁶⁰

Stereotyping

It is suggested that people tend to stereotype others based on their facial appearance.⁶⁴ For example, individuals with signifi-

cant Class II malocclusions and mandibular retrognathia/retrogenia may be seen as weak and possibly idle, whereas individuals with significant Class III malocclusions and mandibular prognathism may be seen as aggressive personality types.

Teasing

Children in the school environment can be unsympathetic and hostile to those with visible differences, with teasing and bullying being everyday occurrences. The frequency of teasing directed at those with visible dentofacial differences is significant.⁶⁵

Severity of deformity

The psychological distress caused by a facial deformity is not proportional to its severity. Research seems to indicate that facial deformities of a mild to moderate nature actually cause patients greater psychological distress than severe facial deformities.⁶⁶ This is thought to be because other people's reactions towards milder deformities are more unpredictable whereas more severe deformities tend to evoke more consistent reactions, albeit negative, allowing the patient to develop better *coping strategies*. The variability in people's reactions to milder facial deformities also results in considerable patient distress. It is important to note that the majority of patients seeking orthodontic treatment or orthognathic surgery fit into the mild/moderate category in terms of facial deformity, as opposed to craniofacial malformation syndromes or severe facial trauma/disease.³

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Chapter 2

Facial Proportions: Classical Canons to Modern Craniofacial Anthropometry

Introduction

‘Beauty consists of due proportion, for the senses delight in well-proportioned things.’

Thomas Aquinas (c. 1225–74), *Summa Theologiae* (1265–73)¹

The concept that ‘ideal’ proportions are the secret of beauty is perhaps the oldest idea regarding the nature of beauty. The assessment of facial beauty is essentially subjective. In the sixteenth century, the artist Albrecht Dürer said, ‘I know not what beauty is, but I know that it affects many things in life.’² Dürer explained that although the concept of facial beauty was immersed in subjectivity, the evaluation of facial proportions could be undertaken objectively. He maintained that disproportionate human faces were unattractive, whereas proportionate features were acceptable even if not always beautiful. Therefore, the appropriate goal for clinical evaluation is the detection of facial disproportions. The inevitable question is, therefore, where did the evidence for ‘ideal’ facial proportions originate?

Ancient Egypt

The ancient Egyptians had a great interest in art and beauty. The famous painted limestone figure of Queen Nefertiti (c. 1350 BC) (Figure 2.1) with her harmonious facial proportions and symmetry is an example of how the Egyptians immortalized the beauty of their kings and queens by depicting them, perhaps unrealistically, with ‘ideal’ facial proportions. Lesser dignitaries were not so honoured and had more realistic depictions in art and sculpture.

Egyptian sculptors worked in granite. They had evolved precise systems for laying out grids on blocks of stone and working inwards according to the matrix provided by the grid.

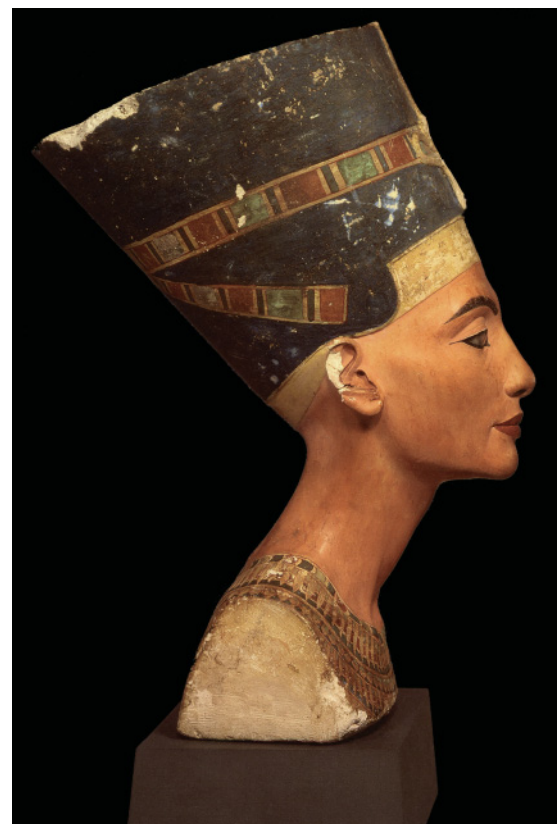


Figure 2.1 Queen Nefertiti. (Egyptian Museum of Berlin.)

The Egyptians had also developed the iron tools necessary for quarrying and carving hard stone. Therefore, the Greeks visiting the Nile sites would have witnessed Egyptian expertise in working with stone rather than with timber.

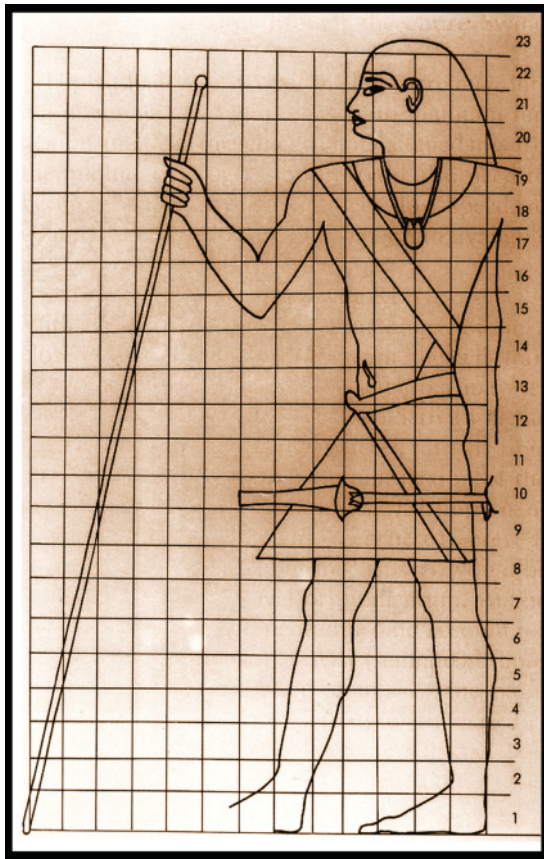


Figure 2.2 Second Egyptian Canon. (Modified from Iversen³ with permission.)

The **Egyptian proportional canons** used grids with meshes of equal sized squares. The **Second Egyptian Canon**, so-called as it was thought to be an improvement on the earlier version, was in use in the seventh century BC. This Second Canon specified a figure height of 19 squares to the shoulders and 22.5 squares to the vertex of the head (Figure 2.2); these exact proportions were used in Greece by the brothers Theodoros and Telekles in creating the Pythian Apollo.³ This was gradually to change with the age of Greek sculpture, which rather than featuring fixed units, began to describe proportion between the parts of the whole human figure.

Ancient Greece

Note

In representing the human form, painters and sculptors in the past developed many canons or guidelines. A **canon** may be defined as a general rule, principle or guideline by which something is judged, and is derived from the Greek *kanon*, meaning 'rule' or 'rod', a unit of standard measurement. It is often difficult to know for certain whether these canons were based on the 'good eye' of the respective artist or whether they used other techniques, such as perhaps measuring attractive individuals, which is essentially anthropometry.

The history of Greek art may be divided into three main periods:

- The Archaic Period (seventh to fifth centuries BC).
- The Classical Period (fifth century BC).
- The Hellenistic Period (323–31 BC).

Of these, the Archaic Period is significant and the Classical Period is the most important.

The Archaic Period

Greek art and sculpture evolved over time. The conceptual and rigid geometric forms developed and used by the Egyptians were gradually abandoned by the Greeks and replaced with the desire to obtain naturalism in art and sculpture.

In the Archaic (literally 'old') Period of Greek art (c. 650–480 BC) statues of young male figures were produced, known generically as *kouroi* (singular *kouros* meaning 'young man') (Figure 2.3).

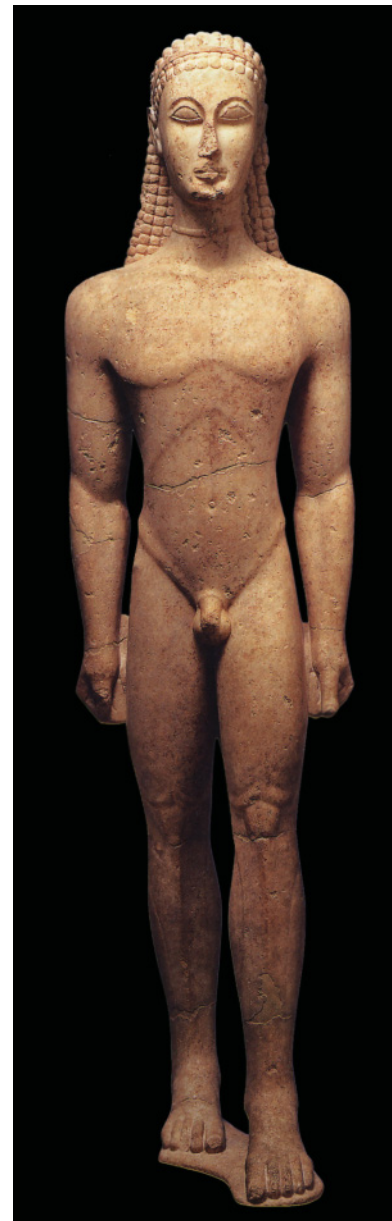


Figure 2.3 *Kouros* from Attica, c. 610–600 BC. (Marble, Metropolitan Museum of Art, New York.)



Figure 2.4 *Kleobis and Biton*; Polymedes of Argos; dedicated c. 580 BC. (Marble, Archaeological Museum, Delphi.)

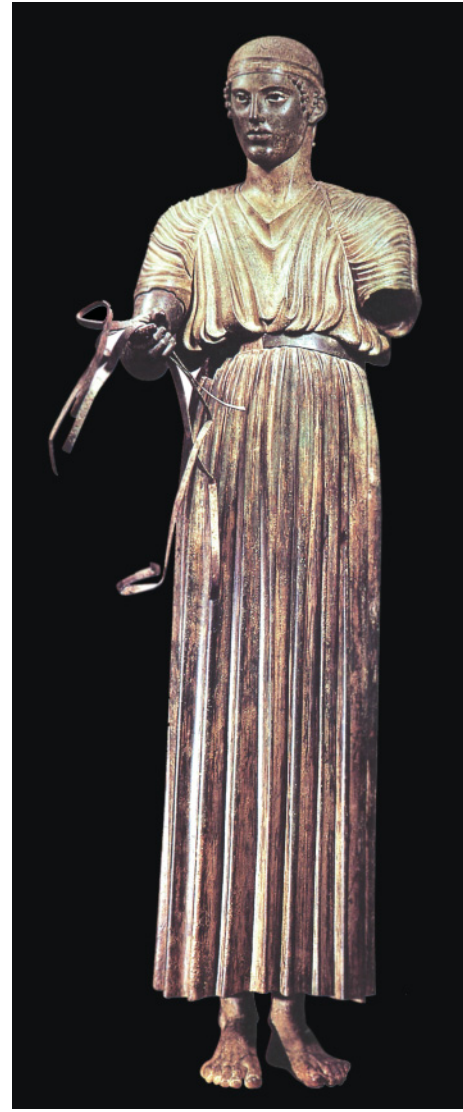


Figure 2.5 *Delphic charioteer*, c. 475 BC. (Bronze, Archaeological Museum, Delphi.)

These were fashioned according to the supposed attributes of the god Apollo, thought to be the epitome of manly excellence: broad shoulders, narrow waist and long hair. One foot, usually the left, was always in front of the other. Sculpting in marble was obviously very difficult, time-consuming and labour intensive. However, the Greek custom of representing their gods in human form relied on using the most precious materials. The time and expense incurred in creating a statue was thought to be proportionate to the delight of the represented god or goddess.⁴

Kleobis and Biton are another famous example of *kouroi* (Figure 2.4). It is estimated that over 20 000 *kouroi* were produced by the end of the sixth century. However, competition between the sculptors meant that stylistic advances became a necessity. Experimentation in form began. The geometrical and rather abstract appearance of the early *kouroi* gave way to an increasingly naturalistic form, with artists producing more life-like images. If Greek gods were to be represented in the form of

athletic young males with 'ideal' figures, then the statues had to be convincing for onlookers.

With the change of the marble *kouroi* towards an increasingly naturalistic appearance came another change; the hollow casting of bronze. Unfortunately few Greek bronze statues survive, as they were vulnerable targets for melting down in turn by future conquerors, the Romans, and then the Christians and Turks.⁵ However, by the early fifth century BC, bronze was the pre-eminent medium for statues, mainly because of its relative lightness. The hollow bronze statues could be easily moved, and even more significantly, this lightness coupled with the strength of bronze enabled the creation of dramatic postures, which would otherwise have been near impossible to achieve in marble, such as an extending arm (Figure 2.5).

The last of the *kouros* genre is the so-called *Kritian Boy* (Figure 2.6). Unlike the earlier *kouros* figures, the weight of the *Kritian Boy* is not evenly distributed on both legs. This is the first known



Figure 2.6 Kritian Boy, c. 480 BC. (Marble, Acropolis Museum, Athens.)

example of *contrapposto*, with movement of the hips to one side being balanced by a counter-movement of the torso about the body's central axis. Together with a slightly turned head this gives the figure a look of relaxed balance rather than rigid symmetry, a requirement that convinced the viewer of potential animation and created a more natural, life-like appearance. The *kouros*-type statue was evolving in the direction of realism, i.e. greater and greater likeness to living man. This led to the most important period of Greek art and sculpture – the Classical Period.

The Classical Period

'Man is the measure of all things.'

Protagoras (c. 485–410 BC),⁶ Greek philosopher



Figure 2.7 Sculpture from Cape Artemision (depicting Zeus launching a thunderbolt or perhaps Poseidon hurling his trident) c. 450 BC. (Bronze, National Archaeological Museum, Athens.)

The ancient Greeks possessed many mythological gods. People made offerings to these gods in order to please them and one of the most important offerings was a statue.⁷ The method of construction of the *kouroi* of the Archaic Period was rigid and stylized, having been copied from the Egyptians. However, in the Classical Period the gods began to take the form of man – this was different to how other civilizations had thus far represented their gods, e.g. with the head of a cat (Egypt) or six arms (India). The classical Greeks began to depict their gods in human form, reflecting back to observers an idealized version of man – something to which man could aspire. The famous statue of the Greek god Zeus (or Poseidon) of Artemision was created as the image of a man, albeit idealized (Figure 2.7). Thus, for the classical Greeks, 'Man' became the 'measure of all things'.

There are two sources of information about this most important period: the historical facts about the statues as mentioned in literary texts and the marble Roman replicas of the original Greek bronze statues. This makes the identification of statues and their attributed creators rather difficult.⁵ However, based on the literary texts and replicas of relatively certain attribution, there are five very important sculptors of the Classical Period:

- **Myron** – (mid-fifth century BC) A contemporary of Polycleitos best known today for his *Discobolos* ('Discus thrower'), available through several marble replicas, which convey the important ability to convince the viewer of animation (Figure 2.8). Unfortunately none of Myron's actual bronze sculptures survive.



Figure 2.8 *Discobolos* ('Discus thrower'), c. 450 BC. Roman copy after a bronze original by Myron. (Marble, Museo Nazionale Romano, Rome.)



Figure 2.9 *Doryphoros* ('Spear-bearer'), also known as the 'Canon', c. 450 BC. Roman copy after a bronze original by Polykleitos. (Marble, Museo Archeologico Nazionale, Naples.)

- **Polykleitos** – (late fifth and early fourth century BC) Among the classical Greek sculptors, Polykleitos has the most recognizable personal style, the 'Polykleitan look'. He wrote the first known treatise on human proportions, the *Canon*, and created a statue which conformed to its proportional guidelines, the *Doryphoros* or 'Spear-bearer', also known as the Canon (Figure 2.9). He may, therefore, be recognized as the 'father' of art theory. Polykleitos is discussed further below.
- **Phidias** – (c. 490–430 BC), a contemporary of Polykleitos, was an Athenian famous as one of the most outstanding of all sculptors. He directed the construction and design of the Parthenon, the chief temple of the Greek goddess Athena on the hill of the Acropolis at Athens. The Parthenon itself, and the statues contained within it, were said to conform to 'ideal' proportions. The Greeks said of Phidias that he alone had seen

the exact image of the gods, and that he revealed it to man.⁷ In ancient Greece, sculpture of the human form was used to represent the many gods. As these sculptures were constructed with ideal proportions, the belief arose that the better 'mortals' looked, the more god-like they were (Figure 2.10).

- **Praxiteles** – (fourth century BC) was the leading sculptor of fourth century BC and one of the wealthiest men in Athens. He is known to have had a mistress, called Phryne, famous for her beauty. Praxiteles defied convention in religious matters. His image of the god Apollo (the far-shooter) showed an idle boy spearing lizards on a tree trunk



Figure 2.10 *Riace warriors*, fifth century BC, possibly by Phidias; the eyes of these bronze statues were made from bone and glass, the teeth from silver, the lips from copper. (Bronze, Museo Archeologico, Reggio di Calabria.)

(Figure 2.11). His image of Dionysus showed him as an infant in the arms of Hermes, originally reaching out for a bunch of grapes that Hermes was holding (Figure 2.12). One of his most famous, or perhaps infamous, statues is the *Aphrodite of Knidos* (Figure 2.13). The most significant factor regarding this statue was Praxiteles' introduction into art and sculpture of the female nude.

- **Lysippos** – (fourth century BC) The last great name in classical Greek sculpture, Lysippos was also probably the most prolific. The replica of his *Apoxyomenos* in the Vatican Museum demonstrates a different proportional canon of head to body height of 1:8, as opposed to the Polycleitan 1:7.5 (Figure 2.14). This proportional canon was later described by the Roman architect Vitruvius and by Leonardo da Vinci in his famous image *Vitruvian Man*.

Of these classical Greek sculptors, the most important name in the history of proportional studies is **Polycleitos** of Argos. **Polycleitos** was one of the most significant figures in Greek

sculpture in the mid fifth century BC. No original examples of his work survive.⁸ However, both literary and archaeological sources confirm that the Romans profoundly admired his work. An important literary source, from the medical writer Galen (second century), describes the following:⁹

‘Chrysippos [late third century BC Stoic philosopher] holds that beauty does not lie in the individual parts of the body, but in the harmonious proportion of the parts – the proportion of one finger to another, of all the fingers to the rest of the hand, of the rest of the hand to the wrist, and of these to the forearm, and of the forearm to the whole arm, and, in short, of everything to everything else, just as described in the *Canon* of Polycleitos. Polycleitos it was who demonstrated these proportions with a work of art, by making a statue according to his treatise, and calling it by the same title, the *Canon*.’

Therefore, the ‘*Canon*’ refers to both the book written by Polycleitos, of which no copies exist, and the Roman marble



Figure 2.11 *Apollo Sauroktonos* ('The Lizard-slayer'), c. 350–340 BC. Roman copy after the original by Praxiteles. (Marble, Musée du Louvre, Paris.)



Figure 2.12 *Hermes and the infant Dionysus*, c. 340–300 BC. Roman copy or possibly the original by Praxiteles. (Marble, Archaeological Museum, Olympia.)

copies of his original bronze statue described as the Canon, otherwise known as the *Doryphorus* ('Spear-bearer') (Figure 2.9). It is not known to what extent the Roman copies of this statue resemble the original. However, there is no reason to think that the Romans would have altered the proportions of the original. The Roman copies are likely to be accurate replicas of the original. Therefore, the 'ideal' proportions suggested by Polycleitos may only be gleaned from examination of Roman copies of the *Doryphorus*.

The source of these 'ideal' human proportions may have been the mathematical principles described by the **Pythagoreans**. In the course of his travels the Greek mathematician **Pythagoras** (sixth century BC) may have come into contact with the math-

ematical treatises of the Egyptians. He postulated that beauty could be explained through mathematical laws and laws of proportion. He proposed an explanation of beauty through a significant finding, that plucking and thereby vibrating strings, of proportionately different lengths under equal tension, produces harmonious notes (Figure 2.15). The difference in the proportionate lengths of the strings followed simple numerical ratios and mathematical laws, and hence his explanation of laws of proportion and their relevance to beauty. The term Pythagoras used to describe beauty was 'cosmos' as he felt that beauty was part of the mathematical order of the universe, hence the origin of the word 'cosmetic'. In an essay entitled 'The Meaning of Beauty in the Exact Sciences', the theoretical physicist and Nobel

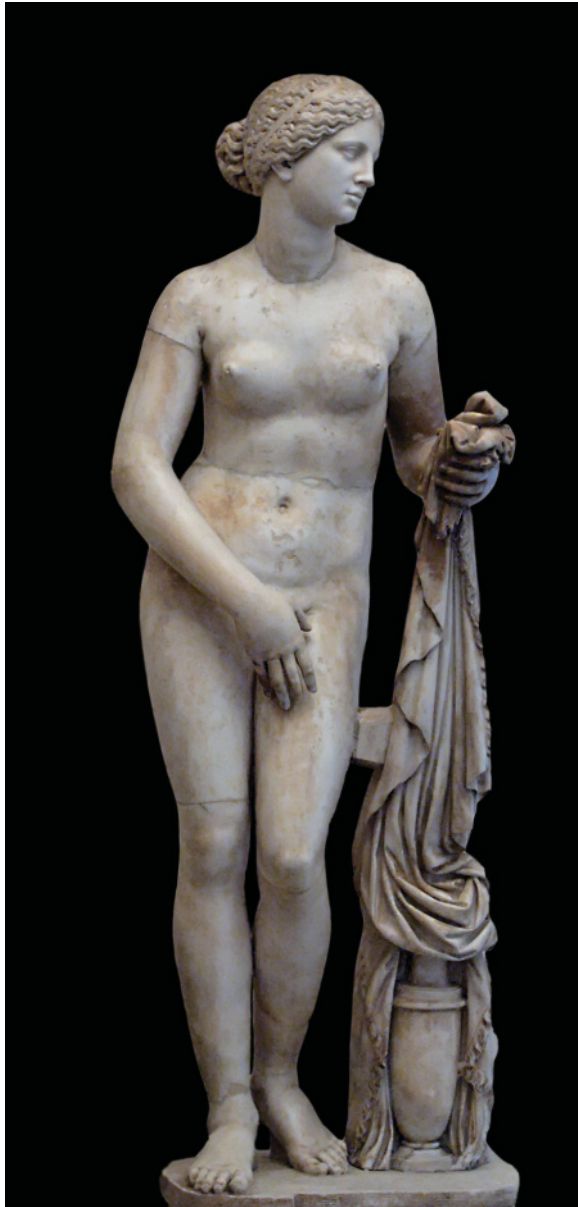


Figure 2.13 *Aphrodite of Knidos*, fourth century BC. Roman copy after the original by Praxiteles. (Marble, Museo Nazionale Romano, Rome.)

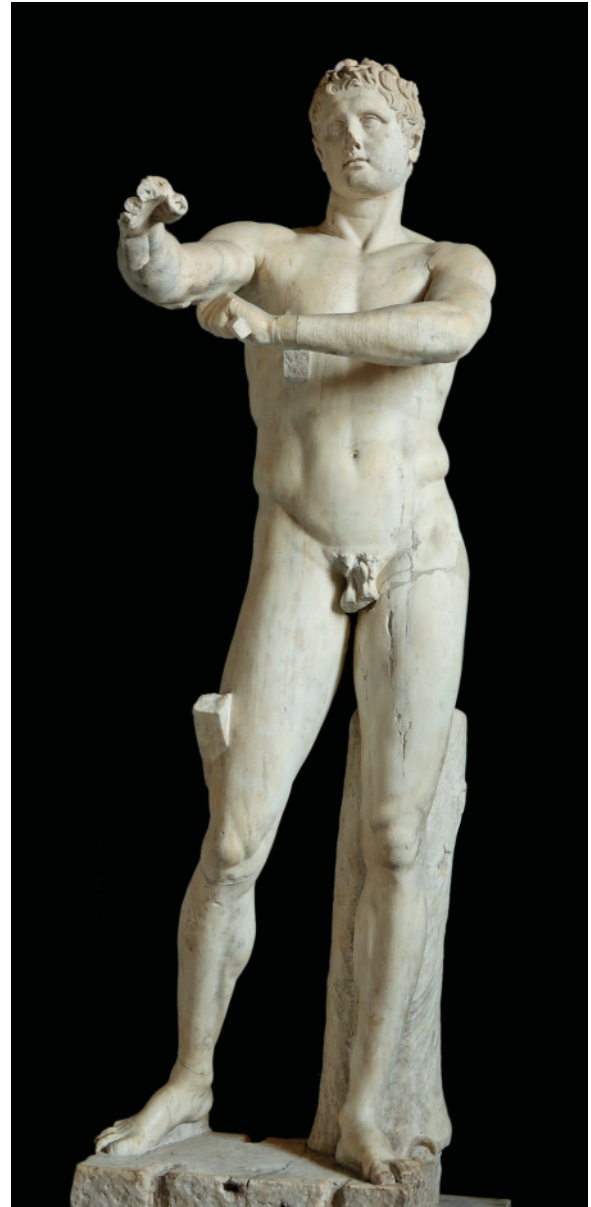


Figure 2.14 *Apoxyomenos* ('The Scraper') of Lysippos. (Roman copy after the Greek original; Vatican Museum.)

laureate Werner Heisenberg referred to this discovery by Pythagoras as 'one of the truly momentous discoveries in the history of mankind'.¹⁰

However, a more realistic assumption is that the proportions are based on **anthropometric measurements** of the human body. The art historian Erwin Panofsky¹¹ suggested that Polycleitos was seeking, in Galen's words, the definition of what 'constitutes beauty'. Therefore, this was unlike the ancient Egyptian grid system, where the human figure was mapped onto a grid according to the estimated position of each part of the body. Polycleitos is more likely to have started with a figure – perhaps an attractive athlete – and tried to calculate how each part of the body related to the rest in terms of proportions.

In the words of Panofsky, classical Greek art 'opposed to the inflexible, mechanical, static and conventional craftsman's code of the Egyptians an elastic, dynamic and aesthetically relevant system of relations'.¹¹

The Roman conquest of Greece

The Roman conquest of Greece occurred in the second century BC. Unfortunately, Greece was subsequently used as a battleground for Roman civil conflicts and Greek art and sculpture suffered badly in this period. Bronze statues were melted to create coins to pay the troops.⁵ Several emperors, in particular the psychopathic Caligula and maniacal Nero, are known to have ransacked prominent sites. Julius Caesar (100–44 BC), however,



Figure 2.15 Depiction of Pythagoras' experiments on the proportional relationships related to harmonious musical notes, in *Theoria Musicae*, Franchino Gaffurio, 1492. (Biblioteca Nazionale Braidense, Milan.)

brought about somewhat of a change as he valued Greek art. His immediate successors, Augustus and subsequently Tiberius followed this tradition for a time. However, as with all empires absolute power coupled with time led to more and more destruction. It was not until the Italian Renaissance that attitudes towards Greek art and sculpture changed from destructive to protective.

Ancient Rome

The Roman architect **Marcus Vitruvius Pollio** (first century BC), better known as Vitruvius, is well known for describing the facial trisection (or **Vitruvian trisection**). Vitruvius referred to the 'symmetrical harmony' of the 'ideal' human body and compared

this to 'perfect buildings'.¹² Vitruvian concepts of proportion and symmetry were essentially based on those of the classical Greek sculptors. Vitruvius' influence continued through his 10-volume work *De Architectura* ('On Architecture'), which he is thought to have dedicated to the emperor Augustus Caesar in about 25 BC (Figure 2.16).

In Book II, Chapter 2, of *De Architectura* Vitruvius defined the concept of **symmetria**, a Greek term which carried implications of 'ideal' proportions beyond our more limited definition of symmetry, while still emphasizing symmetry:¹²

'A proper agreement between the members of the work itself, and relation between the different parts and the whole general scheme, in accordance with a certain part selected as standard. Thus in the human body there is a



Figure 2.16 Depiction of Vitruvius presenting *De Architectura* to Augustus Caesar. (From *On Architecture* by Thomas Gordon Smith, 1684.)

kind of symmetrical harmony ... and so it is with perfect buildings.'

This concept is discussed further in Chapter 11.

In Book III, Chapter 1, entitled 'On symmetry: In temples and in the human body', Vitruvius also described the proportion of head and face height to standing height; he also described the facial trisection, emphasizing that the ideal face can be divided vertically into three distinct facial thirds, a concept still used today in planning facial surgery. He wrote:¹²

'For the human body is so designed by nature that the face, from the chin to the top of the forehead and the lowest roots of the hair, is a tenth part of the whole height; ... the head from the chin to the crown is an eighth, and with the neck and shoulder from the top of the breast to the lowest roots of the hair is a sixth; from the middle of the breast to the summit of the crown is a fourth.

If we take the height of the face itself, the distance from the bottom of the chin to the under side of the nostrils is one third of it; the nose from the under side of the nostrils to a line between the eyebrows is the same; from there to the lowest roots of the hair is also a third, comprising the forehead.

... The other individual parts, too, have their own symmetrical proportions, and it was by employing them that the famous painters and sculptors of antiquity attained to great and endless renown.'

The work of Vitruvius was to be used by the Renaissance artists in developing further theories and canons of facial proportional relationships. Leonardo da Vinci later immortalized aspects of Vitruvian concepts regarding the proportions and symmetry of the human body in his famous *Vitruvian Man*.

Note

Historia Naturalis ('Natural History'), a 37-volume encyclopaedia, is the only surviving work written by the Roman scholar **Pliny the Elder** (Gaius Plinius Secundus), published in the year AD 77. The extract below is from Book VII ('Anthropology and human physiology'), Chapter XVII ('Certain notable observations in bodies of men and women'). This extract is, however, the only sentence written in relation to human proportions. It is quite clear that Pliny is referring to a source; although the origin is not given, it is likely to be Vitruvius:¹³

'It has been observed that the height of a man from the crown of the head to the sole of the foot is equal to the distance between the tips of the middle fingers of the two hands when extended in a straight line.'

Pliny the Elder (AD 23–79)

The Renaissance

The **Renaissance** refers to a progressive cultural period in European history that began in Italy around 1400 and lasted there until the end of the 1500s. Elsewhere in Europe it began later and lasted until the 1600s. An important characteristic of the Renaissance was the rediscovery, translation and study of ancient literature, including Greek and Roman, i.e. a *revival of learning*. Certain notable individuals began to actively search for knowledge rather than accepting what already existed.

The term *rinascità* was coined by the historian Giorgio Vasari (1511–74) in 1550, but the use of the term 'Renaissance' (French for 'rebirth') to describe this period of history was invented by

historians in the 1800s. As with all periods in history, the Renaissance was epitomized by a handful of individuals – scholars who went against the grain of normal society. This led to the Italian term *uomo universale*, the Renaissance ‘universal man’, an individual of universal learning with a broad-ranging knowledge of both the arts and the sciences – a concept epitomized in Leonardo da Vinci. The arts and science were closely tied and influenced each other.

In the history of the development of facial proportional canons another notable individual appeared in the High Renaissance prior to Leonardo; the work of **Leon Battista Alberti** was a considerable influence on that of Leonardo da Vinci.

Leon Battista Alberti

‘Alberti left behind him books written so well that although countless artisans have proved more excellent than him in practice, they have been unable to equal him in writing about their craft.’

Giorgio Vasari (1511–74), *The Lives of the Artists* (1550)¹⁴

Leon Battista Alberti (1404–1472) was a Renaissance architect, scholar and art theorist (Figure 2.17). He is best known for setting out the principles of classical architecture, together with their Renaissance modifications, in *De Re Aedificatoria* (‘On Architecture’). In this book Alberti provided arguably the most interesting definition of beauty ever given:¹⁵

‘Beauty is a form of consonance of the parts within a body (manifested as proportional correspondence in the parts and in the whole), according to number, shape and position, such that nothing may be added, taken away or altered, but for the worse, as dictated by the absolute and fundamental rule of Nature.’

However, he wrote two other works. *Della Pittura* or *De Pictura* (On Painting, c. 1435) was an original work that set forth the principles to be followed by the painter. In this book Alberti described the importance of **human proportional relationships** to beauty:¹⁶

‘care must be taken above all that all the individual parts [of the body] accord well with one another ... one must observe a certain conformity in regard to the size of individual parts.’

He goes on:¹⁶

‘As Nature clearly and openly reveals all these proportions, so the zealous painter will find great profit from investigating them in Nature for himself.’

Alberti finally advises:

‘in assessing the proportions of a living creature we should take one individual part of it by which the rest are measured. The architect Vitruvius reckons the height of a man in feet [Vitruvius, *De Architectura*, Book III, part 1; see above]. I think it more suitable if the rest of the

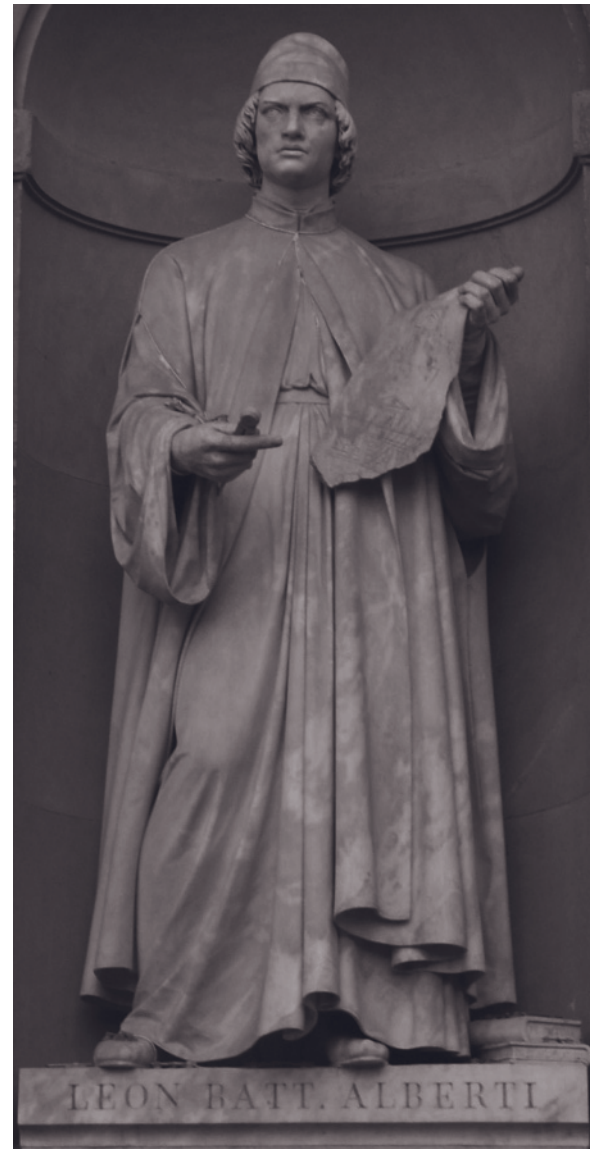


Figure 2.17 Leon Battista Alberti (1404–72). (Courtyard of the Uffizi Gallery, Florence.)

limbs are related to the size of the head, although I have observed it to be well-nigh a common fact in men that the length of the foot is the same as the distance from the chin to the top of the head. ... Having selected this one individual part, the rest should be accommodated to it, so that there is no part of the whole body that does not correspond with the others in height, length and breadth.’^{16,17}

Alberti’s other book, *De Statua* (‘On Sculpture’, unknown date of first publication, but likely to be after 1437) defined the actual ‘ideal’ proportions of man according to his own findings, based on measuring ‘beautiful’ people. Alberti described the term *dimensio* (*dimensio quantitatum*) as:¹⁷

‘The accurate and constant recording of measurements, whereby the state and correspondence of the parts is



Figure 2.19 Leonardo da Vinci (1452–1519), Self-portrait, c. 1515. (Biblioteca Reale, Turin.)

architecture, engineering, human physiology and anatomy (Figure 2.19).¹⁸ He was born in 1452 in the Tuscan hilltown of Vinci, in Italy, and was the illegitimate son of Ser Piero, a Florentine notary; his mother, Caterina, was a young peasant woman. As he was illegitimate, Leonardo was not permitted to learn Greek or Latin – this forced the young Leonardo to learn to think for himself. Leonardo's artistic aptitude appeared relatively early. When he was 15, his father apprenticed him to Andrea del Verrochio, in whose workshop Leonardo received training in painting and sculpture. At the age of 30, Leonardo went to Milan, entering the service of Ludovico Sforza, the Duke of Milan. Leonardo spent the next 17 years in Milan and his scientific studies came to fruition during this period. He studied several treatises including the *De Architectura* of Vitruvius, Piero della Francesca's *De Prospectiva Pingendi* ('On Perspective in Painting') and the translation of *Canon Medicinæ* ('The Canon of Medicine') of the Persian physician and scholar Ibn Sina (Latin name Avicenna; AD 979–1037), which brought about his interest in anatomy. It is interesting that direct anatomical dissection was forbidden during the Renaissance and Leonardo had to conduct anatomical dissection in secret, just as Ibn Sina had done four centuries earlier. Leonardo also became acquainted with the mathematician **Fra Luca Pacioli** (Figure 2.20). In 1494 Pacioli published his *De Divina Proportione* ('On Divine Proportion'),¹⁹ for which Leonardo illustrated a number of



Figure 2.20 Portrait of Luca Pacioli, Jacopo de' Barbari, 1494. (Capodimonte, Naples.)



Figure 2.21 Polyhedron, Leonardo da Vinci, from Pacioli's *De Divina Proportione* (1494). (Biblioteca Ambrosiana, Milan.)

polyhedrons (Figure 2.21) and drew figures of faces with 'ideal' proportions (Figure 2.22).

Leonardo is only thought to have created approximately three dozen paintings. These include the *Last Supper* mural (c. 1495–97; refectory of the monastery of Santa Maria delle Grazie, Milan) and the *Mona Lisa* (c. 1505–14; Louvre, Paris), which are arguably the two most famous works of art in history – certainly

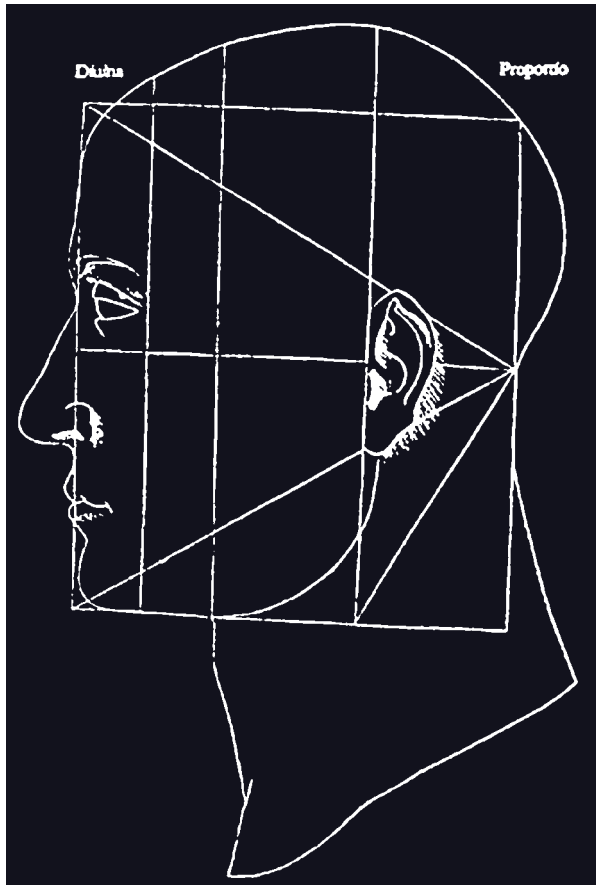


Figure 2.22 Woodcut illustrating the golden proportion as applied to the human facial profile (modified), Leonardo da Vinci, from Pacioli's *De Divina Proportione* (1494). (Biblioteca Ambrosiana, Milan.)

quality over quantity (Figure 2.23). His notebooks and their sketches demonstrate an immensely inventive and enquiring mind, studying various aspects of the natural and scientific world from painting and architecture to mechanics and human anatomy.²⁰

Leonardo's notebooks

It was during his Milanese period that Leonardo embarked on writing his own theory of art. He always stressed the concept of *saper vedere* ('knowing how to see'). From 1490 onwards Leonardo began to write; his studies and diagrams were written down in his notebooks, or on individual sheets of paper, which made up thousands of closely written and abundantly illustrated pages. Of these, a number of codices have been prepared and preserved, including the Windsor Collection (Royal Library, Windsor) and the Codex Atlanticus (Biblioteca Ambrosiana, Milan) collected by the sculptor Pompeo Leoni at the end of the sixteenth century; and the Arundel Manuscript (British Museum).²¹ His writings, although never completed, may be interpreted as preliminary stages of works destined for eventual publication. In the margin of one of his anatomical works he implores his 'colleagues' to see that his works are printed.¹⁸

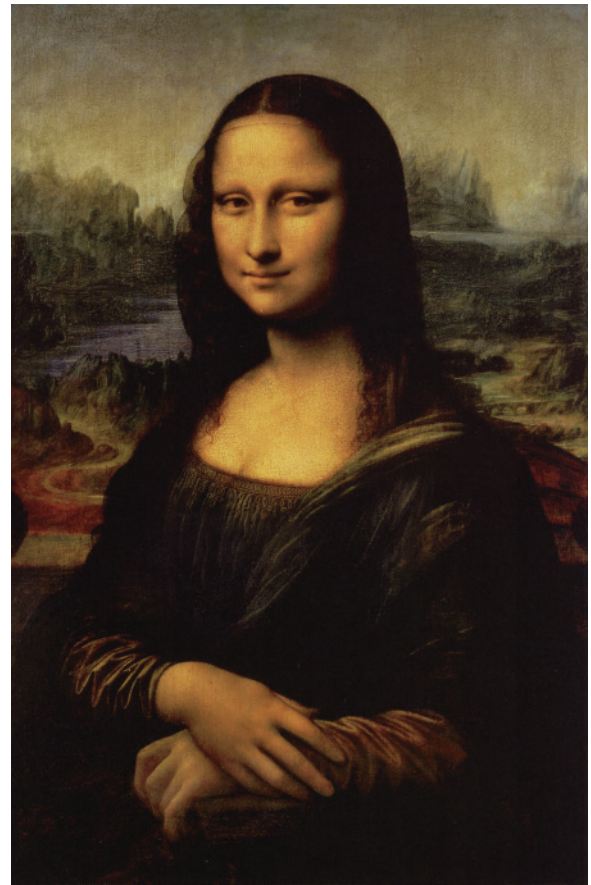


Figure 2.23 *Mona Lisa* (c. 1505–14), Leonardo da Vinci. (Musée du Louvre, Paris.)

Note

Leonardo's use of **mirror-writing** has been the subject of conjecture for many years, with some claiming it as a secret form of handwriting. However, the truth is simpler and far less exciting. Leonardo was left-handed, so mirror-writing prevented his own hand from smudging the ink as he wrote. His writing may be read clearly and without difficulty with the aid of a mirror.

It is from Leonardo's notebooks and associated sketches that his theories and ideas regarding human proportions, and his quest for the ideal **facial proportions** may be gleaned. Leonardo defined proportion as the *ratio between the respective parts and the whole*.²² Leonardo advised that beautiful faces and figures should be chosen and measured in order to find the ideal proportions – but he stresses:²³

'make an effort to collect the good features from many beautiful faces, but *let their beauty be confirmed rather by public renown than by your own judgement*.' [emphasis added]

This advice forms the foundation of modern research into perceptions of facial attractiveness. Leonardo advises:²⁴

‘Measure on yourself the proportion of the composition of your limbs, and if you find any discordant part, take note of it and make very sure that you do not adopt it in the figures that are composed by you ...’

Note

Leonardo's studies on proportional relationships were based on measurements of living individuals, i.e. **anthropometry**. This followed the Albertian method.

Leonardo's iconic figure of *Homo vitruvianus* or *Vitruvian Man* (Figure 2.24), which Leonardo based on guidelines described by Vitruvius, albeit with his own corrections and modifications, represents ‘ideal’ male proportions based on man's navel as the centre of the perfect geometrical forms, a circle and a square, enclosing man with outstretched arms. This figure is a useful starting point for a study of Leonardo's proportions studies. Leonardo also produced studies of the proportions of the human head (Figure 2.25). The most important of these figures are presented here with a selection of Leonardo's notes that are relevant to the description of his **proportional canons** as related to the study of craniofacial proportional relationships (Figures 2.26–2.29).^{18,22–24} A number of other Leonardo sketches of proportional relationships are presented and discussed in Part 2 of this book.

In addition to Leonardo, a number of other Italian masters made enormous contributions to art and each made subtle additions to the understanding of human beauty – among them the great **Michelangelo Buonarroti** (1475–1564) (Figure 2.30), **Sandro Botticelli** (1445–1510) and **Raphael** (1483–1520). These Italian masters made substantial contributions to the understanding of human proportions and significantly advanced the understanding of scientific perspective in art.

Note

It is worth noting that the first translator of Vitruvius' treatise *De Architectura* from Latin into a modern language, i.e. Italian, was the architect and architectural theorist **Cesare Cesariano** (1475–1543). It was published, with copious woodcut illustrations, at Como, in 1521. Among his illustrations is an attempt at rendering Vitruvius' concept of the ‘ideal’ proportions of a man (Figure 2.31). Cesariano was unable to adequately convey the relationship of ‘ideal’ proportions to the ideal geometrical figures of circle and square; his created image thereby has huge hands and elongated feet! A number of other fifteenth-century art theorists attempted to draw the concept of Vitruvius, which was eventually successfully rendered by Leonardo as the now iconic *Vitruvian Man*. A number of lesser known Italian artists also attempted to further Leonardo's studies of proportion; among them was **Carlo Urbino** (1525–85) (Figure 2.32).

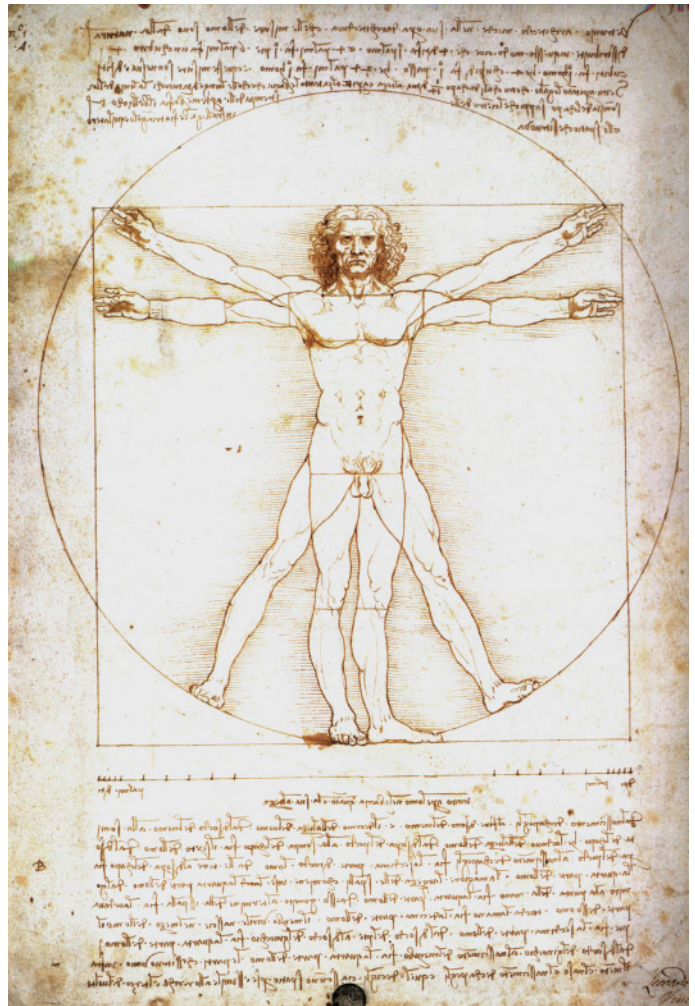


Figure 2.24 *Vitruvian Man*, c. 1490, Leonardo da Vinci (Gallerie dell'Accademia, Venice); Leonardo's notes translate as (additional notes are in square brackets):

‘Vitruvius, the architect, says in his work on architecture that the measurements of man are arranged by Nature ... and these measures are those of his buildings. If you open your legs so as to decrease your height by 1/14th and open and raise your arms so that your longest fingers touch the level of the top of your head, you should know that the centre of the outspread limbs will be the navel, and the space described between the legs will be an equilateral triangle.’

The span of a man's outspread arms is equal to his height.”

From the start of the hair [i.e. hairline or trichion] to the bottom of the chin is a tenth of a man's height; from the bottom of the chin to the top of the head is an eighth of a man's height. ... The distance from the bottom of the chin to the nose and from the hairline to the eyebrows is, in each case the same, and as with the ear, a third of the face [i.e. the Vitruvian facial trisection].’

Artists outside Italy often travelled through Italy in order to attempt to understand the usefulness of these new principles. Among these was the greatest German artist of the Northern European Renaissance – **Albrecht Dürer**.



Figure 2.25 *Male Head in Profile with Proportions*, c. 1490, Leonardo da Vinci. (Gallerie dell'Accademia, Venice.)



Figure 2.26 *Leonardo's Square* (Detail, Study of proportions and study of horsemen for the Battle of Anghiari, c. 1490, Leonardo da Vinci (Gallerie dell'Accademia, Venice.) Leonardo's notes translate as (additional notes are in square brackets):

'From the eyebrow to the junction of the lip and chin [mentolabial fold], to the angle of the mandible to the upper angle where the ear joins the side of the head will be a perfect square. Each side by itself is half the head.'

'The hollow of the cheek below the cheekbone occurs halfway between the tip of the nose and the back of the lower jawbone, which is at the lower part of the ear.'

'From the back of the eye-socket to the ear is the same as the height of the ear, which is one-third of the face height.'

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Figure 2.27 *Study of Proportions of the Human Head and Figure (detail)*, c. 1490, Leonardo da Vinci, Royal Library, Windsor. (With kind permission from The Royal Collection © 2010 Her Majesty Queen Elizabeth II.) Leonardo's notes translate as (additional notes are in square brackets):

'From a to b, that is from the hairline to the top of the head, should be equal to the distance c–d, that is from the bottom of the nose to the meeting of the lips [upper lip height].'

'From the inner corner of the eye m [medial canthus] to the top of the head a, should be equal to m down to the bottom of the chin s [i.e. the craniofacial bisection].'

's c f b are all equal distances from each other [i.e. the facial trisection].'

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Figure 2.28 *Proportions of the Face in Profile (detail, and redrawing with description)*, c. 1490, Leonardo da Vinci, Royal Library, Windsor. (With kind permission from The Royal Collection © 2010 Her Majesty Queen Elizabeth II.) Leonardo's notes translate as (additional notes are in square brackets):

A: 'The distance between the parting of the lips and the base of the nose, a–b, is one-seventh of the face [i.e. upper lip height].'

B: 'The distance from the mouth to the bottom of the chin, c–d [i.e. lower lip and chin height], should be a quarter of face height and equal to the mouth width.'

C: 'The distance from the chin to the base of the nose, e–f, should be a third of the face height and equal to the height of the nose and to the forehead [i.e. the facial trisection].'

D: 'The distance between the midpoints of the nose to below the chin, g–h, is half the face height.'

E: 'The distance from the top of the nose, where the eyebrows meet [i.e. glabella] to the bottom of the chin, i–k, is two-thirds of the face height.'

F: 'The distance from the parting of the lips to the top of the chin, i–m, that is where the chin ends and passes into the lower lip [i.e. lower lip height], is the third of the distance from the parting of the lips to the bottom of the chin and is a twelfth part of the face. From the top to the bottom of the chin, m–n [i.e. chin height] is the sixth part of the face and will be a fifty-fourth part of standing height.'

G: 'From the furthest projection of the chin to the throat, o–p [submental or horizontal 'throat' length], is equal to the distance between the mouth and the bottom of the chin, and is a quarter part of face height.'

H: 'The distance from the top of the throat to the bottom of the neck, q–r [i.e. vertical neck height] is half the face height and the eighteenth part of standing height.'

Figure 2.29 *Proportions of the Face and Nose* (redrawn), c. 1490, Leonardo da Vinci, Royal Library, Windsor. (With kind permission from The Royal Collection © 2010 Her Majesty Queen Elizabeth II.) Leonardo's notes translate as (additional notes are in square brackets):

'The nose will make two squares, that is to say, the width of the nose at the nostrils goes twice into the height between the base of the nose and the start of the eyebrows [i.e. nasal width is half of midfacial height].'

'In profile, the distance between the extreme edge of the nostril – where it joins the cheek – and the tip of the nose is the same size as between one nostril and the other seen from the front [i.e. nasal projection is equal to nasal width].'

'If you divide the entire height of the nose into four equal parts, that is to say, from the base to where it joins the eyebrows, you will find that one of these parts is equal to the distance from above the nostrils to the base of the nose [alar height], and the upper part is equal to the distance between the tear duct in the inner corner of the eye and the point where the eyebrows begin; and the two middle parts are of a size equivalent to the width of the eye.'

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Figure 2.30 Portrait of Michelangelo Buonarroti, c. 1522, Giuliano Bugiardini (?). (Musée du Louvre, Paris.)

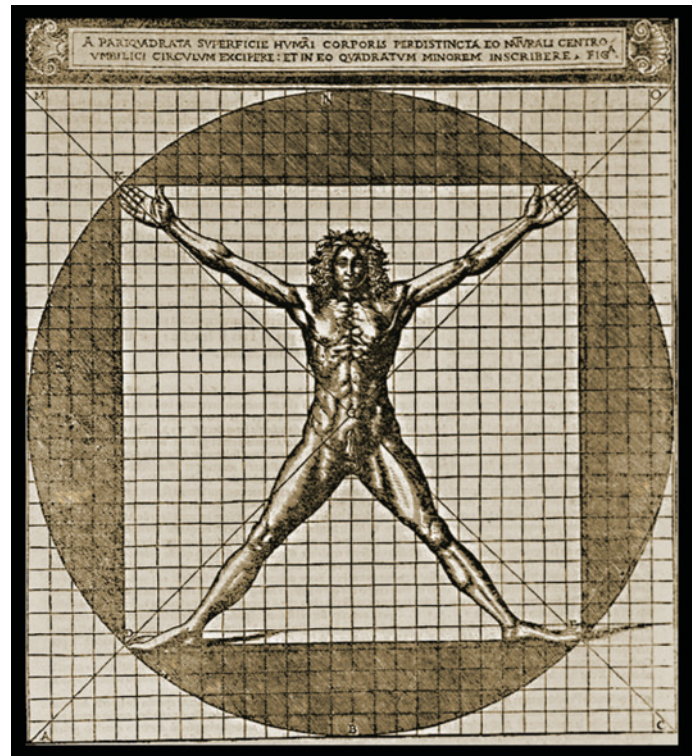


Figure 2.31 *Vitruvian Man*, 1521, Cesare Cesariano, from Cesare Cesariano's translation of Vitruvius' treatise *De Architectura*.

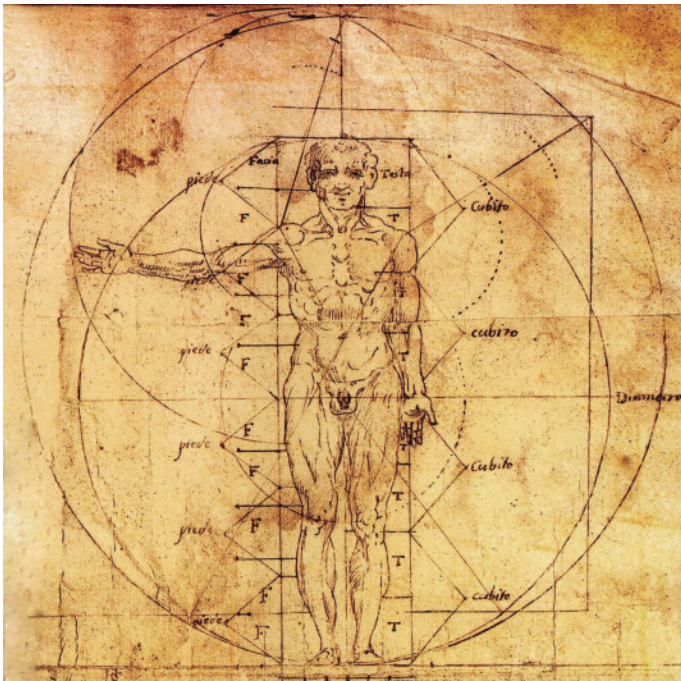


Figure 2.32 Vitruvian Man, 1570, Carlo Urbino.

Albrecht Dürer

‘these artists ... they have not learnt Geometry, without which no one can either be or become an absolute artist.’

Albrecht Dürer, *The Art of Measurement* (1525)²

Albrecht Dürer (1471–1528), generally acknowledged as the greatest German Renaissance artist, was born in Nuremberg, the son of a Hungarian goldsmith (Figure 2.33). His gift for drawing was noticed at a young age and he was apprenticed to learn woodcut illustration. Following this he began to travel to broaden his understanding of artistic techniques.²⁵ He travelled to Italy in 1494 and 1506 primarily to study the techniques of Italian painting. In Italy, his search began to find the factors that create beauty in the human form – this he found in the work of the classical writers and the southern Renaissance masters of Italy. He preferred the Italian style and in 1506, he wrote to a friend: ‘Here I am a gentleman. At home only a parasite.’ Dürer made contact with Luca Pacioli and by observing a number of Leonardo’s drawings developed a profound respect for Leonardo’s work. These may have been the inspiration for his extensive proportional studies. Among the first of his studies was the engraving of *Adam and Eve* (Figure 2.34), which is said to embody the ‘ideals’ of beauty and proportions from the time. However, Dürer was still not content and travelled to Venice to continue his learning.

On his return from Venice, Dürer began intensive studies designed to find and understand the proportions of the human



Figure 2.33 Albrecht Dürer (1471–1528), Self-portrait, 1500, Bayerische Staatsgemäldesammlungen, Munich.

body. Though he had begun with a search for ‘ideal’ proportions, his return from Venice saw a change in his approach. Dürer became convinced that there was no such thing as ‘absolute beauty’ or ‘ideal proportions’ in the human form – instead there were many forms of ‘relative beauty’. Thus he began by ‘investigating about two or three hundred living persons’, which provided the **anthropometric data** for his comprehensive treatise on human proportions *Vier Bücher von Menschlicher Proportion* (‘Four Books on Human Proportions’).²⁶ Rather than providing canons of ‘ideal’ proportions, he demonstrated a range of different male and female proportions depending on the body type, some depicted in three dimensions (Figure 2.35), though the ‘mean’ image was similar to Leonardo’s ‘ideal’ (Figure 2.36). Dürer’s book, thereby, laid the foundations for **scientific anthropometry**.

The first of the ‘Four Books on Human Proportions’ – which together with the theoretical writings of Leonardo da Vinci are among the most important Renaissance contributions to the theory of art and human proportions – was proofread by Dürer himself. Unfortunately, Dürer died on the 6 April 1528 and did not live to see the publication of the book on 31 October of the same year. Important illustrations from Dürer’s book are presented in Part 2 of this book.

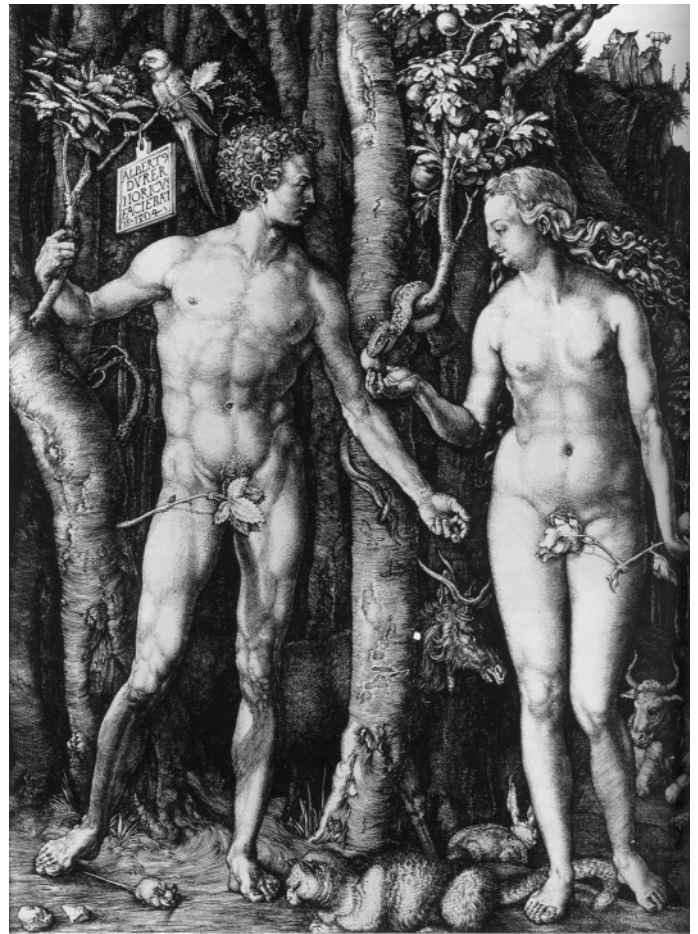


Figure 2.34 *Adam and Eve*, 1504, Albrecht Dürer.

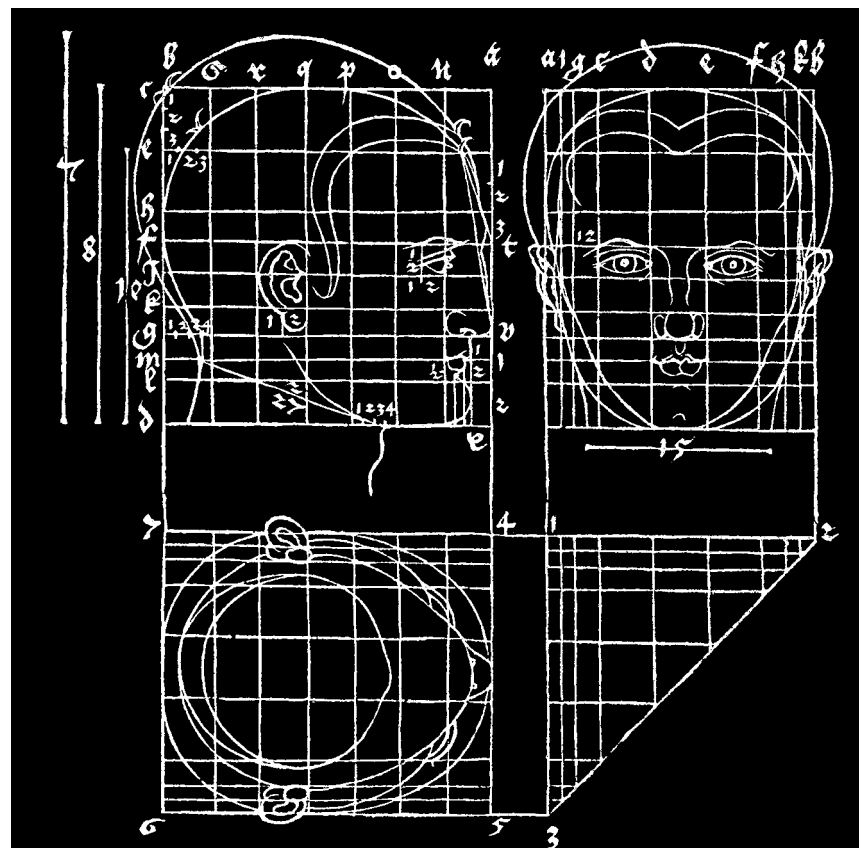


Figure 2.35 *'Ideal' Craniofacial Proportions in Three Dimensions*, 1528, Albrecht Dürer. (Modified from *Vier Bücher von Menschlicher Proportion*.²⁶⁾

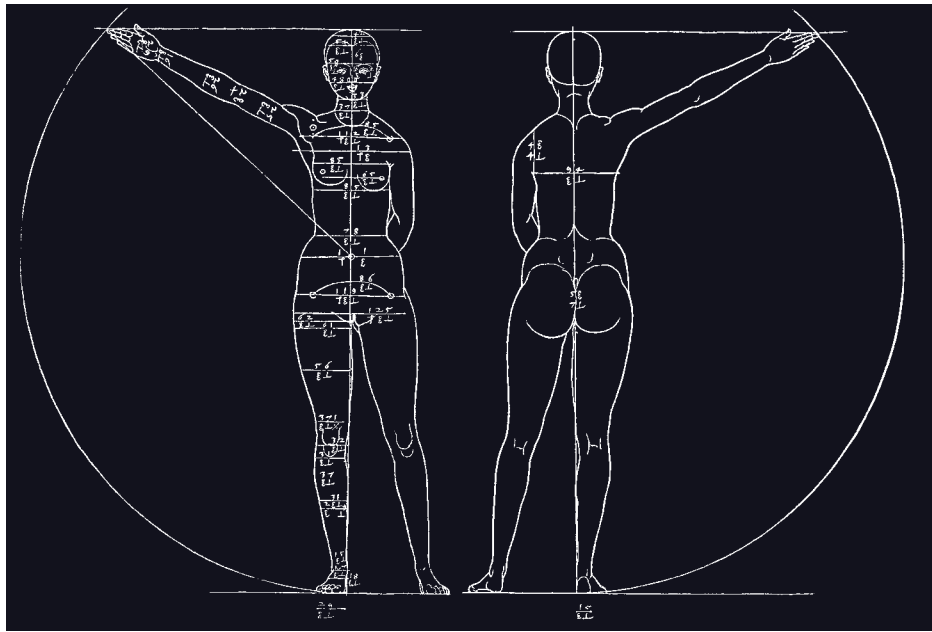


Figure 2.36 'Ideal' Female Proportions, 1528, Albrecht Dürer. (Modified from Vier Bücher von Menschlicher Proportion.²⁶)

'For, verily, art is embedded in Nature; whoever can draw her out, has her ...; Some talk about how human beings ought to look ...; but I consider Nature as master and human fancy as a fallacy; ... the Creator has made men as they should be, and I believe that the true shapeliness and beauty is inherent in the mass of all men; to him who can properly extract the right measure I will give more credence than to him who wants to establish a newly thought-up proportion in which human beings have had no share.'

Albrecht Dürer, *Vier Bücher von Menschlicher Proportion* (1528)^{25,26}

The Enlightenment and neoclassicism

The **Enlightenment** refers to a European intellectual movement by certain notable individuals of the late seventeenth and eighteenth centuries, which emphasized rational and scientific knowledge and a move away from traditional dogma; reason was to begin to replace superstition. **Neoclassicism** refers to an artistic style and movement originating in Europe, Rome in particular, in the mid-eighteenth century, characterized by a revival in interest in antiquity and the Classical Era.

Neoclassical canons of proportion

In the period known as the Enlightenment much was written about the concept of beauty in relation to the abstract idea of aesthetics; these arguments have been described in Chapter 1.

However, some of the artists of the era also began to revisit and sometimes attempted to revise the classical and Renaissance canons of proportion, thereby leading to what are sometimes described as the **neoclassical canons of proportion**. Most of these canons were simply the reworking of the same classical and Renaissance ideas and principles.

To define the neoclassical canons, the art academics of the seventeenth century began to measure the Roman replicas of classical Greek statues in an attempt to find the formula for classical beauty. These 'statue measurers' looked at every proportional relationship they could find. The French engraver **Gérard Audran** (1640–1703) studied in Rome for three years. He wrote a book on human proportions entitled *Les Proportions du Corps Humain mesurés sur les plus belles figures de l'Antiquité* (1683), based on proportional relationships of classical statues (Figure 2.37).²⁷ This book was studied extensively in the European art academies of the eighteenth and nineteenth centuries, in the pursuit to define 'ideal' beauty.

However, this quest became somewhat more scientific with the work of the German sculptor **Johann Gottfried Schadow** (1764–1850) (Figure 2.38). Schadow studied in Rome for three years, which formed his style. In 1788 he returned to Berlin as sculptor to the court and eventually became director of the Berlin Academy of Art. He had an interest in measuring classical statues, particularly those attributed to **Polycleitos**; yet he also developed an interest in measurement of people, which forms the basis of **anthropometry**, and wrote a treatise on the proportions of the human figure, entitled *Polycleitos* (Figure 2.39).²⁸ In this period a further movement began, which though not directly

Les parties du visage d'une Venus antique mesurées de leurs memes grandeurs

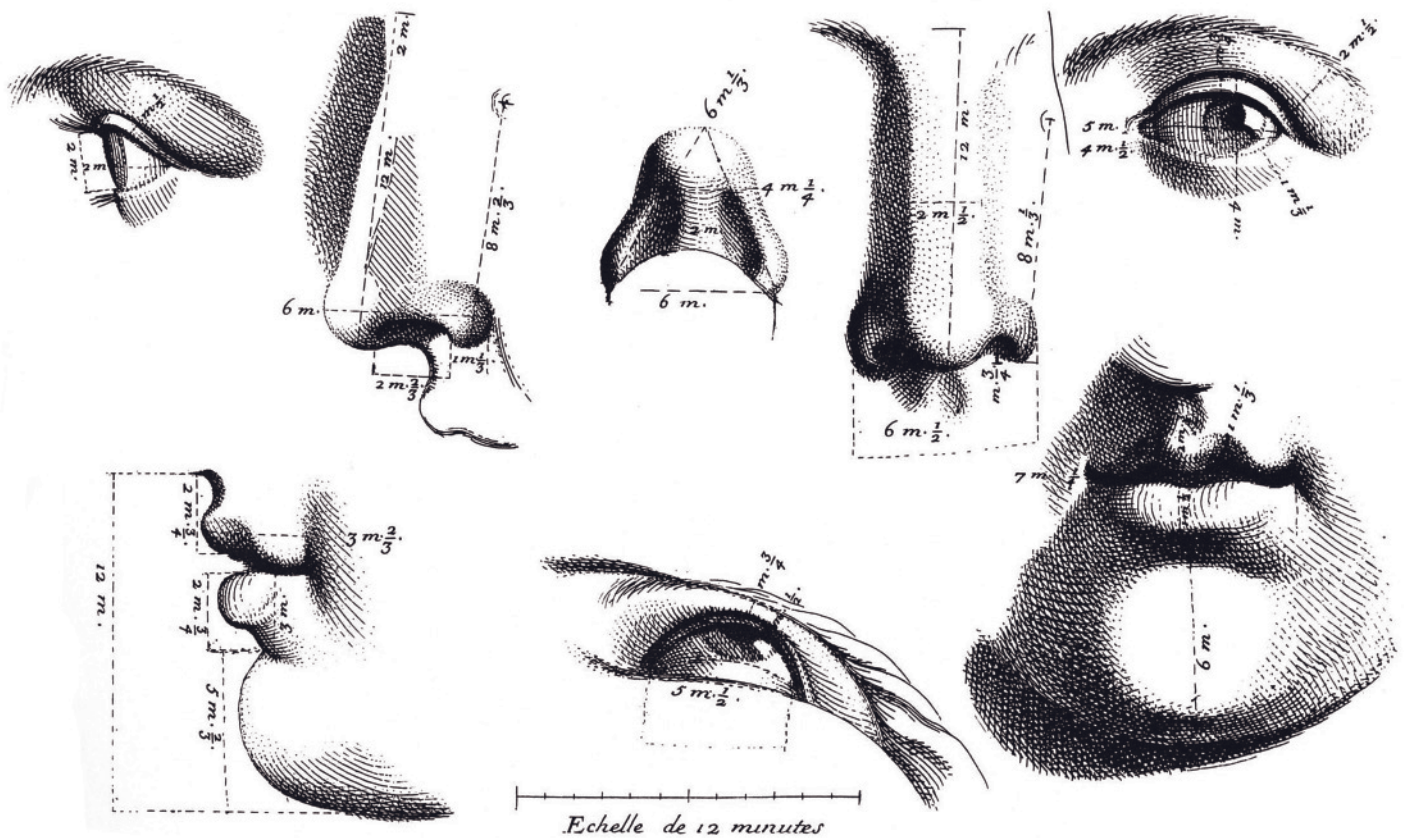


Figure 2.37 Ideal proportions of a woman, based on measurements of classical statues, 1683, Gérard Audran (*Les Proportions du Corps Humain mesurés sur les plus belles figures de l'Antiquité*²⁷).

related to the study of facial proportions, affected the understanding of the craniofacial complex – **craniometry** – the scientific measurement of skulls.

Craniometry

Petrus Camper (1722–89) was a Dutch physician, anatomist, anthropologist and zoologist (Figure 2.40). He was one of the first scientists of the Enlightenment to interest himself in **comparative anatomy**. He described the principle of correlation in all organisms, which he termed ‘metamorphosis,’ particularly the similarity between human beings and other vertebrates.²⁹

Petrus Camper is also known for developing the **facial angle** (Figure 2.41). This angle is formed by the intersection of two lines: the vertical *linea facialis*, from the front of the maxillary incisor teeth to the most prominent part of the forehead, and the horizontal line from the nasal base (or anterior nasal spine in a skull) to the mid-tragus of the ear (or middle of the external auditory meatus in a skull), better known as **Camper’s plane**.

Camper determined that modern humans had facial angles between 70° and 90°, with African angles closer to 70°. He claimed that classical Greco-Roman statues presented an angle of 95–100°, the angle descending through Europeans of 90°, Orientals of 80°, black people of 70°. Re-examination of Camper’s original work proves that his facial angle was intended to correct the racial prejudices of Europeans.²⁹ The differences in the facial angle demonstrated the physical variety of humanity and actually provided an indirect argument for the equal worth of that variety. After lifelong observations of mammalian and human crania in various stages of life, Camper speculated on the laws behind the existing diversity of cranial morphology. After comparing sagittal sections of various skulls, he argued that uniformity was evident in the brain cavity’s oval form, but that the key to ethnic differences rested in the variable extension of the jaws and their resulting impact on craniofacial morphology. He wrote:²⁹

‘Be Adam created black, brown, tanned or white, his descendants, as soon as they spread out over the wide



Figure 2.38 Johann Gottfried Schadow (1764–1850), Lithograph 1830, depicted holding a spreading caliper.

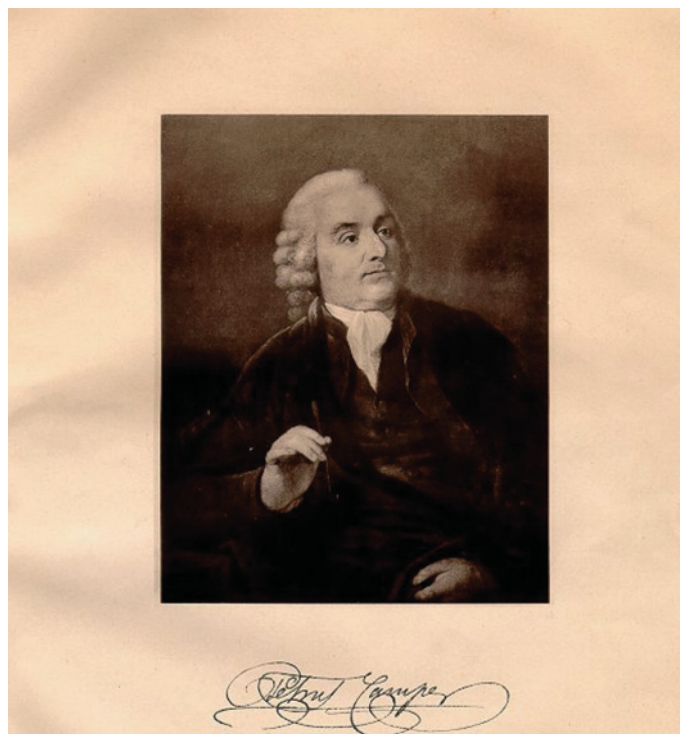


Figure 2.40 Petrus Camper (1722–89).

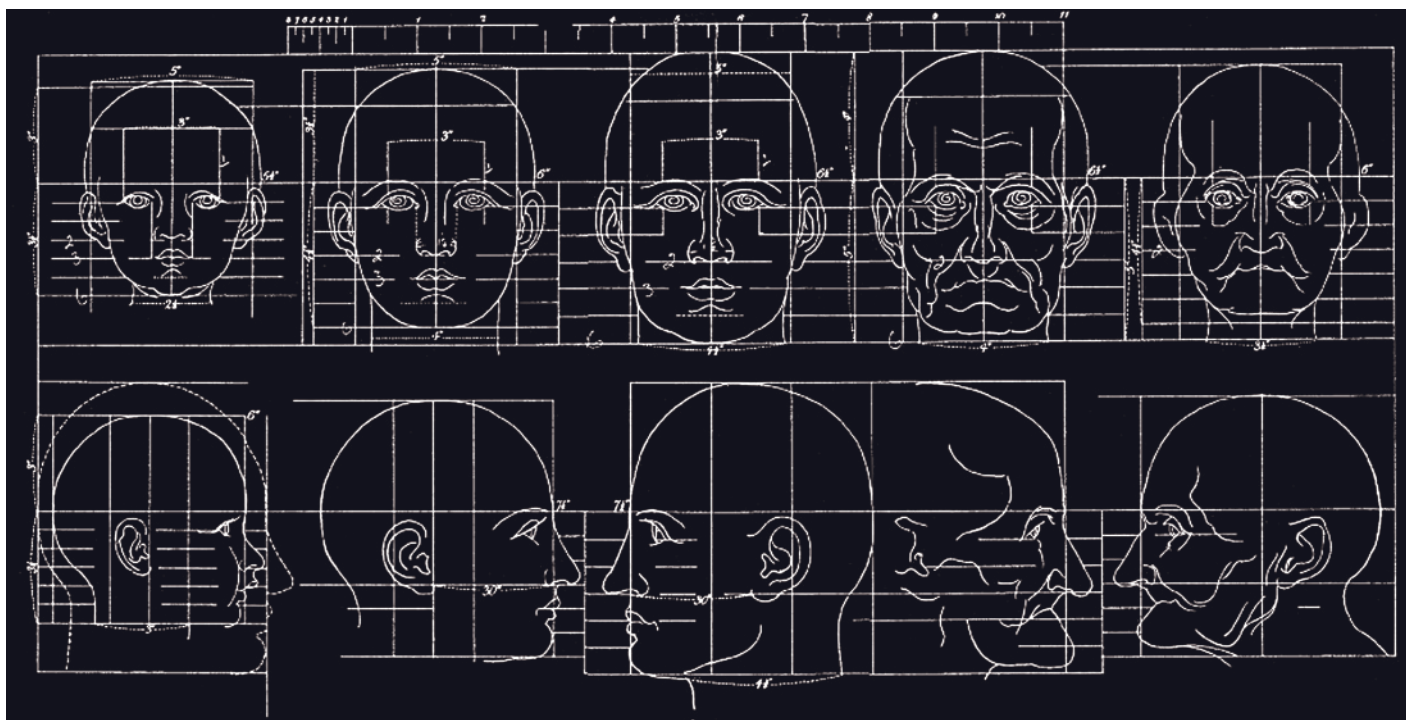


Figure 2.39 Proportions of the human head and ageing. (Redrawn from *Polycleitos* by Johann Gottfried Schadow.)

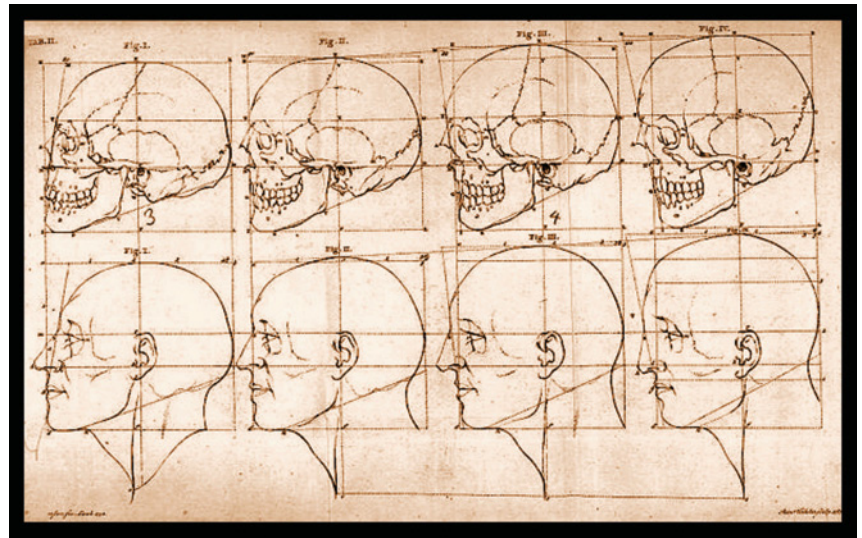


Figure 2.41 Variations in the facial angle, depicted by Petrus Camper (late eighteenth century).

surface of the earth, necessarily had to change in colour and shape according to how the country, the particular foods and illnesses differed.’

The main importance of Camper’s work on craniometry was that it laid the foundation for future study of craniofacial morphology through another technique – **radiographic cephalometry**.

Twentieth century

Two important advances in the twentieth century in the understanding of facial proportional relationships and the structural relationships of the craniofacial complex were the development of **modern craniofacial anthropometry** and **orthodontic cephalometry**. The development of orthodontic cephalometry is described in detail in Chapter 7.

Modern craniofacial anthropometry

From the late nineteenth century two separate schools of anthropometry emerged – French and German. Lack of communication and competition meant difficulty in establishing any unified system of measurement. Eventually the International Congress of Prehistoric Anthropology and Archaeology met in Monaco in 1906, then again in Geneva in 1912, making some progress, although no concrete agreements were reached. Further progress halted with the outbreak of the First World War. Two versions of the work of these two commissions were eventually published; the first was by the Swiss-German anthropologist Rudolf Martin and represented the German School. The second was written by the Czech physician and physical anthropologist **Aleš Hrdlička** (1869–1943) (Figure 2.42), a student of the French anthropologist Leon Manouvrier. Hrdlička eventually emigrated to the USA

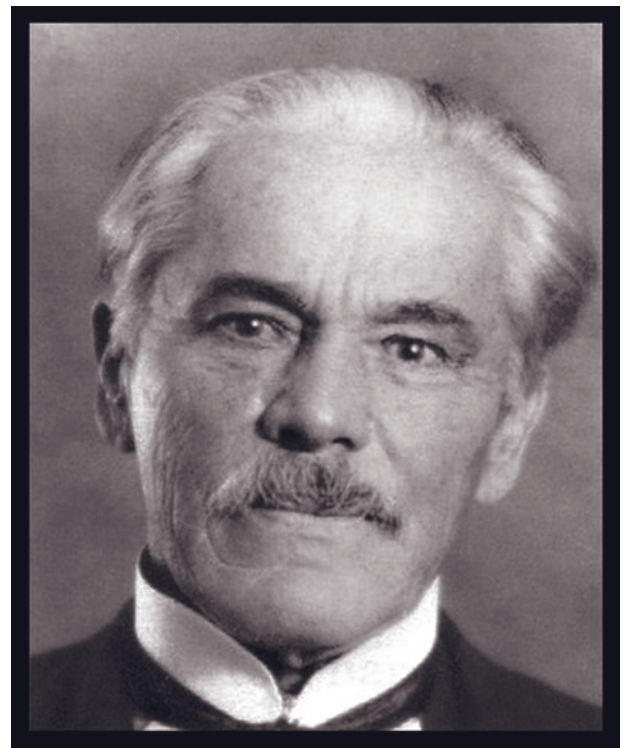


Figure 2.42 Aleš Hrdlička (1869–1943).

and established the Division of Physical Anthropology of the Smithsonian Institution. His book entitled *Anthropometry* (1920) became a standard text.³⁰

In the 1960s the chairman of the Department of Plastic Surgery at Charles University in Prague, František Burian,

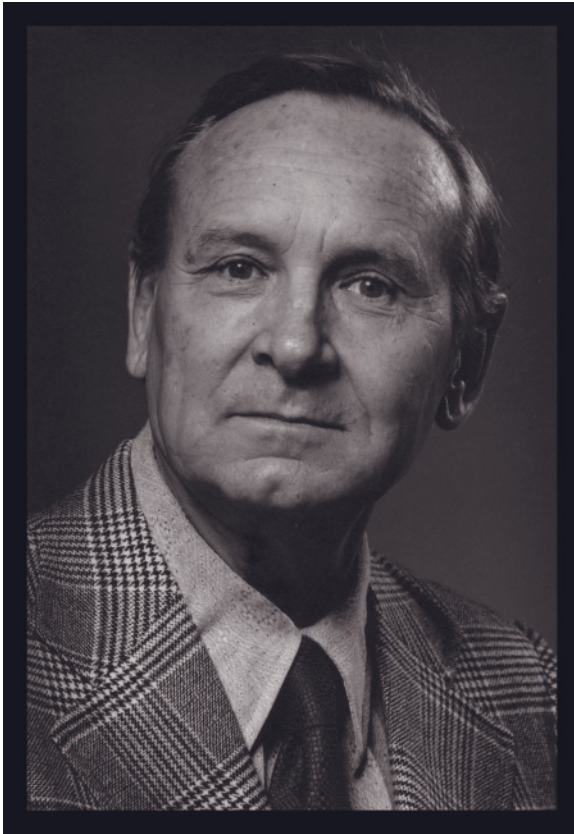


Figure 2.43 Leslie G Farkas (1915–2008) – the father of modern craniofacial anthropometry.

enlisted the help of another physical anthropologist familiar with Hrdlička's methods – **Karel Hajniš** – in order to develop an objective system of evaluating the results of surgery on patients with clefts of the lip and palate. Hajniš began to work with one of the plastic surgeons in recording a multitude of craniofacial anthropometric measurements of these patients – the surgeon's name was **Leslie Gabriel Farkas**.

Leslie Farkas – the father of modern craniofacial anthropometry

Leslie Farkas was born on the 18 April 1915, in Rózsahegy, Hungary (present day Slovakia) (Figure 2.43). At age 11, he was enrolled in a Hungarian school run by Benedictine priests in Komárom, where he received a classical education, which included a functional knowledge of Latin and classical Greek. Following in his father's footsteps and upon the urging of his physician uncle, he entered medical school at Comenius University in Pozsony (now Bratislava). He graduated in 1941. On graduation, he was drafted into the Slovak army and was sent to serve as a military doctor in the Second World War.

Following the war, Farkas moved to Prague where he became a member of the plastic surgery team at Charles University. His

supervisor, Professor František Burian, became a professional mentor and encouraged him in his research work. He received his Certificate of Plastic Surgery in 1956, his PhD in 1959, an Associate Professorship in 1965, and a doctor of sciences degree in 1968. His dissertation work for the DSc degree – on the surgical techniques for hypospadias – was published in his first book, *Hypospadias* (1967).

Farkas' interest in craniofacial morphology began during his period in Prague. Early in his surgical career, he became dissatisfied with the determination of the morphological changes in the head and face by visual assessment. Thus, he began to explore the use of classical anthropometric methods for the quantitative analysis of faces pre- and post-operatively. He collaborated with anthropologist Professor Karel Hajniš to develop an empirical system of facial measurements to analyse the faces of patients with cleft deformities and facial deformities due to trauma.

In 1968, he was invited by Dr William K Lindsay to develop this research work at the Hospital for Sick Children in Toronto, Canada. Amid political upheaval in Prague in 1968, he emigrated to Canada. His first project there involved research dealing with tendon graft healing, tracheal defect repair and the morphology of the cleft-lip-palate face. Employed at the Hospital for Sick Children in Toronto, he continued exploring his interest in craniofacial anthropometry. Since **normative data** did not exist, he spent much of his career measuring faces and compiling a huge database of norms. He soon realized, however, that just taking linear measurements was not enough. The relations of measurements, that is – **craniofacial proportions** – are of paramount importance in the evaluation of the craniofacial complex. These research findings were published in a book, *Anthropometric Facial Proportions in Medicine* (1987), co-edited with the surgeon Ian R Munro.³¹ His continued research, together with related topics, was published in two editions of *Anthropometry of the Head and Face in Medicine* (1981, 1994).³²

Farkas was very much aware that the North American white normative data he compiled could not be applied to different ethnic groups. He took great effort to collect as diverse data as possible to differentiate the *normative data of different ethnic groups* while encouraging scientists from around the world to collect their own population's normative measurements. He travelled the world to measure Chinese and African faces. One of his last wishes was to embark on the collection of craniofacial morphometric data of some local Canadian aboriginal groups. Unfortunately this did not happen before he died peacefully on the 16 October 2008, having published 244 scientific works and the above-mentioned four books.

Thus Leslie Farkas generated a detailed body of work, over nearly half a century, of craniofacial anthropometric data, making a major contribution to our understanding of the craniofacial complex. The normative data relate to children and adults, normal and 'attractive', comparison of different ethnic groups and comparison with various craniofacial deformities. It is for this that he is the acknowledged 'father' of modern craniofacial anthropometry.

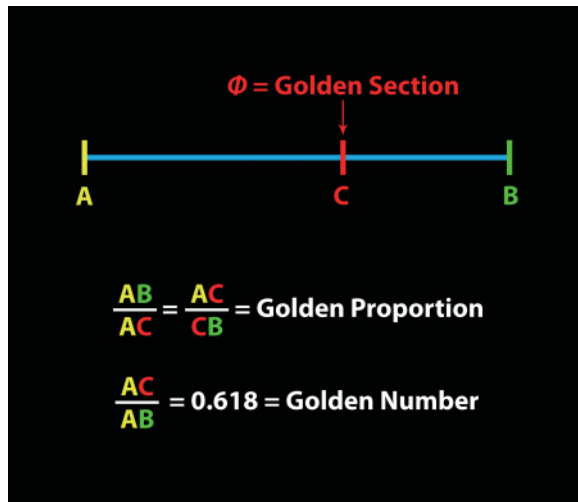


Figure 2.44 The golden proportion.

The golden proportion

We have seen that throughout the ages, painters and sculptors have attempted to establish ideal proportions for the human form. However, possibly the most famous of all axioms about ‘ideal’ proportions is that of the **golden proportion**.³³

The golden proportion is a geometrical proportion in which a line AB is divided at a point C in such a way that $AB/AC = AC/CB$ (Figure 2.44). That is, the ratio of the shorter section to the longer section of the line is equal to the ratio of the longer section to the whole line. This gives AC/AB the value 0.618, termed the **golden number**. The point at which the line is divided is known as the **golden section** and is represented by the symbol Φ (phi) derived from the name of the Greek sculptor Phidias. Phidias directed the construction and design of the Parthenon, the chief temple of the Greek goddess Athena on the hill of the Acropolis at Athens. The Parthenon itself, and the statues contained within it, were said to conform to ‘ideal’ proportions, with Phidias possibly incorporating the golden proportion into the architectural design,³⁴ though this is, at best, merely conjecture.

This proportion has classically been described as pleasing to the eye, the emphasis being upon the proportion of the parts to the whole. The prominent mathematician **Euclid** (c. 325–265 BC) described this in his treatise *The Elements*. In his edition of *Euclid's Elements*, the mathematician **Luca Pacioli** (1509) renamed the golden proportion the ‘Divine proportion’ as he felt the concept could not be fully explained, and published a treatise entitled *De Divina Proportione* (‘On Divine Proportion’) for which Leonardo da Vinci drew figures of symmetrical and proportionate polyhedrons and human faces.¹⁹ Maestlin gave the first known calculation of the golden proportion as a decimal in a letter to his former pupil, the famous astronomer **Johannes Kepler** in 1597.³⁵

Another often quoted concept, which is said to give some credence to the golden proportion, is the Fibonacci sequence.



Figure 2.45 Leonardo Pisano (1170–1240), also known as Leonardo Fibonacci.

Leonardo Pisano, or Leonardo of Pisa (1170–1240), also known as **Leonardo Fibonacci**, was the most distinguished mathematician of the Middle Ages (Figure 2.45). He devised a number sequence in which each number is the sum of the two preceding numbers, i.e. 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, etc. In the nineteenth century the mathematician Edouard Lucas coined the term **Fibonacci sequence**, and scientists began to discover the numbers in nature, such as in the spirals of sunflower heads, the logarithmic spiral in snail shells and in animal horns. As the numbers increase in magnitude, the ratio between succeeding numbers approaches the golden proportion.

Attempts have been made to apply the concept of the golden proportion to dental aesthetics. In terms of smile aesthetics the golden proportion may be applied to the apparent mesiodistal width of the anterior teeth when viewed from the frontal aspect. This may be useful in designing the relative width of teeth in a beautiful smile (see Chapter 24).³⁶

There have also been attempts to correlate ideal facial proportions with the golden proportion.³³ However, the faces of professional models have not been found to always fit the golden proportion,³⁷ and a study looking at the aesthetic improvement of patients undergoing orthognathic surgery found that while most subjects were considered more aesthetic after treatment than before, the proportions were equally likely to move away from or towards the golden proportion.³⁸ Therefore, more evidence is required to substantiate the true significance of this fascinating yet debatable concept in the clinical assessment of facial aesthetics.

The ongoing problem with research into the golden proportion

‘The intensity of a conviction that a hypothesis is true has no bearing on whether it is true or false.’

Sir Peter Medawar (1915–87), *Advice to a Young Scientist* (1979)³⁹

If a research study is undertaken to analyse various facial proportions with the aim of finding whether there is a number linking the proportional relationships, the research methodology may be said to be relatively free of bias. Unfortunately, most of the studies that have been undertaken begin with the golden number, and then look for proportional relationships that conform to it! If the researcher looks hard enough then they are bound to find some proportional relationships that fit their hypothesis. This is incorrect and biased research methodology. To paraphrase Medawar, the intensity of the conviction that a specific number is the secret to beauty has no bearing on whether it is true or false.

Conclusion

The evidence for the guidelines used by clinicians today for what constitutes ‘ideal’ facial measurements and proportional relationships are based on those initially described in art and sculpture, albeit somewhat modified from the original based on modern anthropometric and cephalometric studies of population averages and ranges of normal variation. The clinical implications of this information are described in Part 2.

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Chapter 3 Facial Expression: Influence and Significance

‘Expression is the dress of thought’

Alexander Pope, An Essay on Criticism (1711)¹

Introduction

A **facial expression** may be defined as a look on someone’s face that conveys a particular emotion, e.g. happiness or sadness. The human ability to convey emotions via facial expressions is fundamental for daily existence. Our ability to communicate is an essential prerequisite for social interaction at all levels. The clinical correction of facial deformities is, therefore, not only vital for alteration of static facial appearance towards normal, but also in allowing patients the ability to express themselves and their emotions.

Human facial expressions are so significant in life that humans have devised numerous methods to try to hide their emotions or true feelings by attempting to alter their facial expressions, e.g. the ‘poker face’, ‘keeping a straight face’, ‘putting on a brave face’. However, more often than not human emotions are said to be ‘written all over one’s face’. The term has even found its way into the arts – **Expressionism** is defined as a style of painting, music or drama in which the artist or writer seeks to express the inner world of emotion rather than external reality. This is very similar to humans communicating their inner feelings by facial expressions.

The Norwegian artist Edvard Munch’s painting *The Scream or The Cry* (1893) is seen as a symbol of modern spiritual anguish (Figure 3.1). The dramatic perspective used in this painting, which is Munch’s most famous work, is said to represent what the artist himself described as an ‘infinite scream passing

throughout Nature.’² It depicts a simultaneously corpse-like and sperm-like central figure, whose contours are reflected in the swirling lines of a blood-red sky. However, the painting’s power is heightened by the *instantly recognizable panic-stricken facial expression* of the central character. It is this facial expression that ultimately conveys the artist’s intensity of anxiety to the observer.

Importance of facial expressions

‘When the eyes say one thing and the tongue another, a practised man relies on the language of the first.’

Ralph Waldo Emerson, ‘Worship’, in *The Conduct of Life* (1860)³

In human beings, the manifestation of emotions and feelings is revealed by virtue of facial expressions. *A great deal of human communication takes place without the need for words.* Therefore, the importance of facial expression is inextricably linked to the significance of **non-verbal communication**. The psychologist Albert Mehrabian (b. 1939) has described three key elements in face-to-face communication, often referred to as Mehrabian’s **7%–38%–55% Rule**.^{4,5} This ‘rule’ states that only 7% of communication involves words, with non-verbal communication dominating (38% tone of voice, 55% body language). The non-verbal elements are particularly important for effective and meaningful communication about **emotions**. The three parts of the message, described as the 3Vs (verbal, vocal and visual) need to support each other, i.e. they have to be **congruent**. If they are **incongruent**, i.e. if words and body language disagree, one tends to believe the body language.

Image not available in the electronic edition

Figure 3.1 *The Scream* (1893), Edvard Munch. (© Munch Museum/Munch–Ellingsen Group, BONO, Oslo/DACS, London 2010.)

While the exact numbers in Mehrabian's 'rule' may be challenged, the important point is that a great deal of face-to-face communication is through non-verbal communication. Without seeing non-verbal cues, much of which relies on facial expressions, it is easier to misunderstand the words and thereby misunderstand the person.

Clinicians tend to evaluate patients in **static** positions. However, people see, observe and make judgements about other people via their facial expressions, i.e. in a **dynamic** state. Therefore, facial expressions and the ability to make them are vital for everyday life and the essential ability to communicate. Dentofacial and craniofacial deformities can make the ability to express oneself through facial expressions very difficult, with an observer potentially misinterpreting a patient's emotions in the presence of a significant facial deformity. This may potentially lead to **negative stereotyping**. For example, patients with severe mandibular deficiency and/or excessively protruding maxillary incisors may appear rather unintelligent, particularly when smiling; this is also the case for 'long face' deformity and 'gummy smiles'. Patients with mandibular excess tend to appear aggressive and a smile may appear more akin to a grimace. Patients with maxillary deficiency often have downturned oral commissures, thus appearing angry or sad. Patients with facial palsy and even the inadvertent use of botulinum toxin in the endeavour to reduce facial wrinkles can have disastrous consequences on the ability to display facial expressions and thereby communicate effectively.

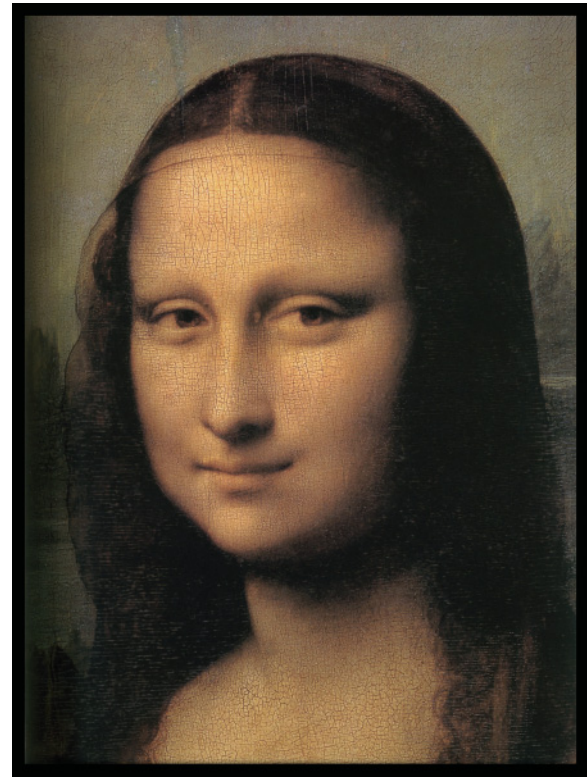


Figure 3.2 Detail of the *Mona Lisa* (c. 1505–14), Leonardo da Vinci. (Musée du Louvre, Paris.)

The difficulties a patient may face in their life and social interactions will not be restricted to their static facial appearance, but to their ability to convey their emotions and communicate via facial expressions. Therefore, the inability to convey emotions, whether due to a disease process or a developmental disorder of growth, is extremely significant.

History of research into facial expressions

The importance of facial expressions and the innate ability to recognize the basic emotions (**universal expressions of emotion**) has an evolutionary basis. Many animals use **facial signals** to communicate and the reason facial expressions often outdo verbal communication is likely to be because communication via facial expressions predates communication via language. Prior to the scientific study of facial expression came the practice of **physiognomy**, i.e. the supposed skill of judging character from facial features.

Artists have also demonstrated the importance of expressions. Classical Greek sculpture, in particular, eventually moved away from the rigid features depicted in older statues towards giving the illusion of movement; part of the 'life' in the statues was from the expression of a smile. The importance of facial expression in art at the highest level is that of Leonardo da Vinci's *Mona Lisa*, arguably the most famous painting in the world (Figure 3.2). The

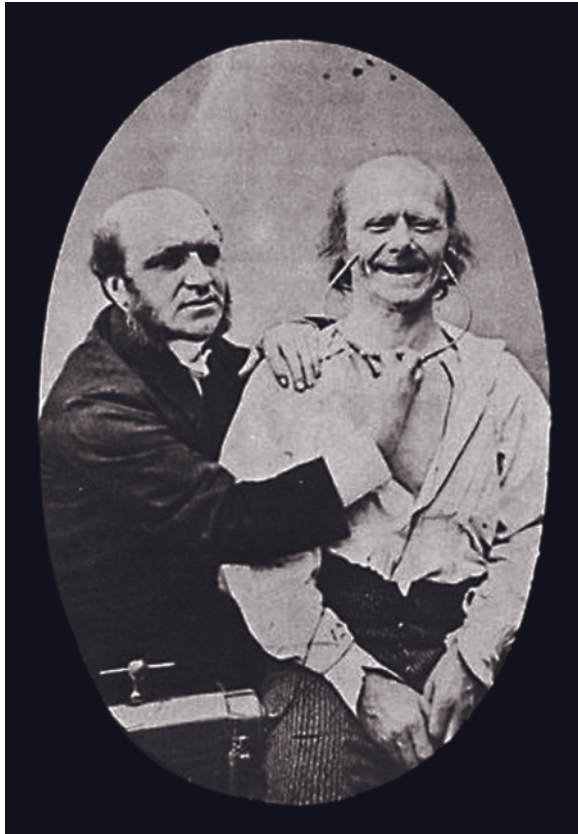


Figure 3.3 Duchenne de Boulogne with 'The Old Man'.

famous expression of the *Mona Lisa* is almost entirely based on the eyes and the smile, which are the most expressive regions of the face.

Research into facial expression has yielded many discoveries. Due to the importance of evaluating patients in animation (the 'dynamic' state), clinicians should have an understanding of these findings.

The work of Duchenne

The art of **photography** has been responsible for helping to create a science in the study of facial expression. In the nineteenth century, the pioneering French neurophysiologist **Guillaume-Benjamin-Amand Duchenne de Boulogne** (1806–75) began a series of experiments to understand the neural pathways to the face (Figure 3.3).⁶ He would collect newly severed heads from the guillotine and place live electrodes on the face; this technique was not particularly satisfactory, for obvious reasons. Duchenne eventually found his principal photographic subject, 'The Old Man', who was afflicted with almost total facial anaesthesia. This circumstance made him an ideal subject for Duchenne's investigations, because Duchenne could use stimulating electrodes on various facial muscle insertions while using the newly invented medium of photography to capture electrically induced expressions on his subject's face (Figure 3.4); the electrodes used would otherwise certainly have been somewhat uncomfortable, if not actually painful.

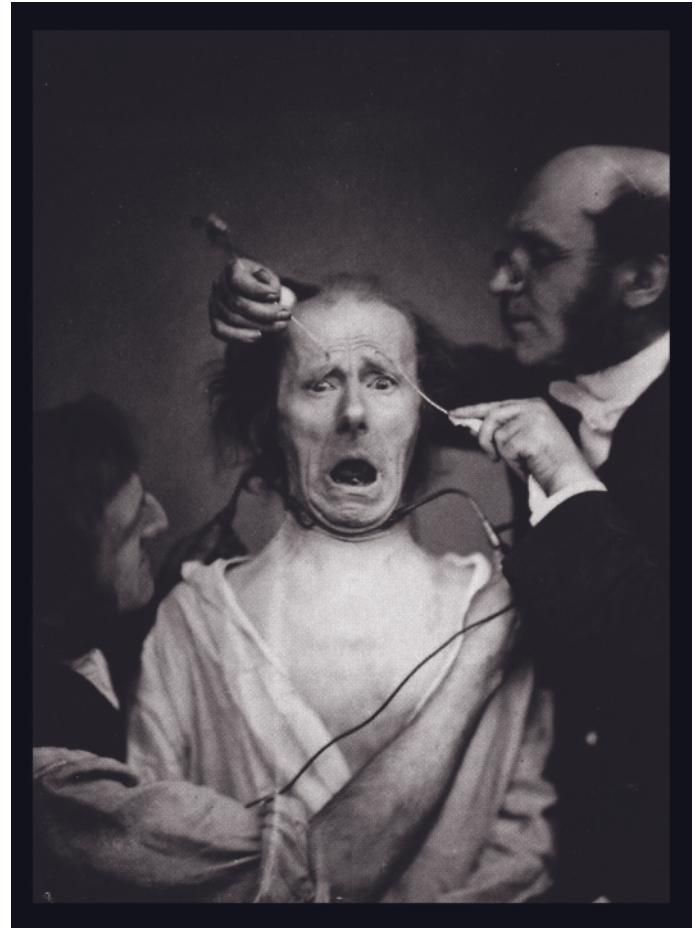


Figure 3.4 Duchenne using stimulating electrodes on various facial muscle insertions while using photography to capture electrically induced expressions on 'The Old Man's' face.

Duchenne published *The Mechanisms of Human Facial Expression* in French in 1862.⁶ His fascinating photographs and insightful commentary provided generations of researchers with the foundations for experimentation and the understanding of facial expression. Subsequent researchers from Charles Darwin to Paul Ekman all acknowledge their debt to Duchenne.

Note

The **muscles of facial expression** originate from the facial skeleton and insert, directly or indirectly, into the facial skin, making the facial surface highly mobile and able to form a myriad of shapes (Figure 3.5).

The work of Darwin

'Darwin is the man to whom we all owe a debt of gratitude.'

Paul Ekman (2003)⁷

Charles Darwin (1809–82) (Figure 3.6) published *The Expression of the Emotions in Man and Animals* in 1872, one year after *The Descent of Man*. In fact, the book was originally intended to be

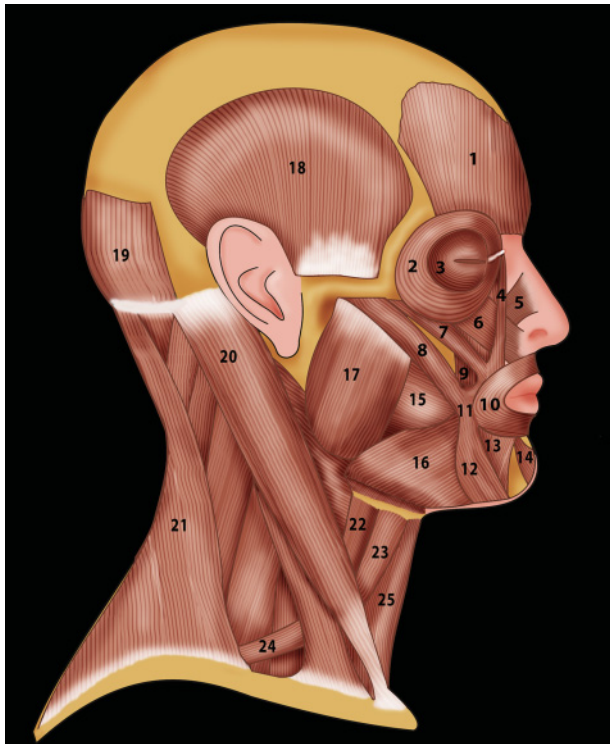


Figure 3.5 Muscles of facial expression and other superficial muscles of the head and neck.

- 1 Frontal belly of occipitofrontalis
- 2 Orbital part of orbicularis oculi
- 3 Palpebral part of orbicularis oculi
- 4 Levator labii superioris alaeque nasi
- 5 Nasalis
- 6 Levator labii superioris
- 7 Zygomaticus minor
- 8 Zygomaticus major
- 9 Levator anguli oris
- 10 Orbicularis oris
- 11 Modiolus
- 12 Depressor anguli oris
- 13 Depressor labii inferioris
- 14 Mentalis
- 15 Buccinator
- 16 Platysma (cut)
- 17 Masseter
- 18 Temporalis
- 19 Occipital belly of occipitofrontalis
- 20 Sternocleidomastoid
- 21 Trapezius
- 22 Thyrohyoid
- 23 Omohyoid (superior belly)
- 24 Omohyoid (inferior belly)
- 25 Sternohyoid

a chapter in *Descent*. Thus began the scientific study of the facial expressions of emotion. Darwin argued that emotions are not unique to humans (Figure 3.7), but may be found in many animals (Figure 3.8).⁸ His answer to the question of why a particular facial expression was linked to a particular emotion gave

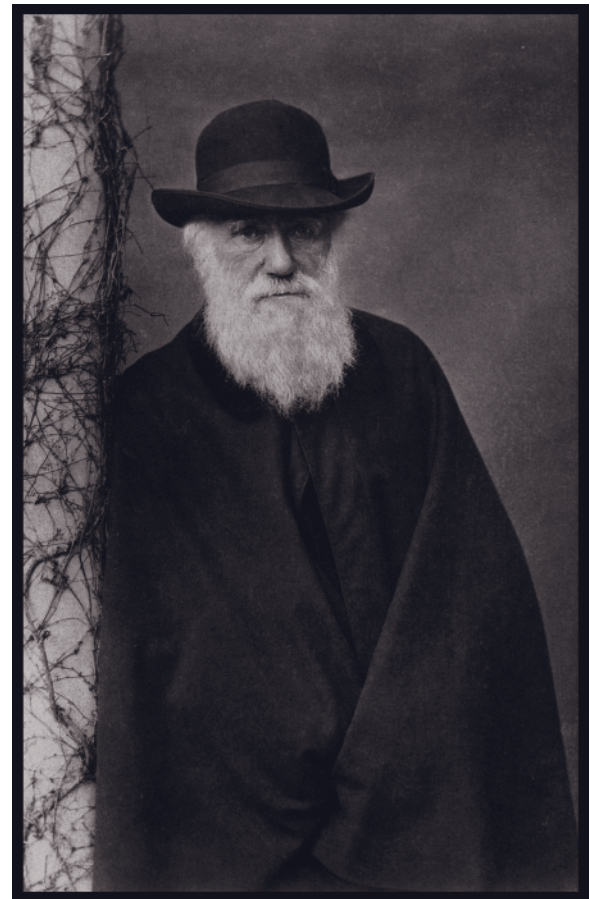


Figure 3.6 Charles Darwin, aged 72 (1881).

further weight to his theory of the continuity of species and evolution.

Darwin's evidence was the analysis of replies from a number of world travellers regarding the facial expressions they encountered for various emotions around the world. Darwin's conclusion was that facial expressions were universal, which demonstrated further evidence for the common descent of humankind and affirmed, in Darwin's own words, 'the unity of mankind.'⁸ Darwin showed various people pictures taken by Duchenne de Boulogne and asked them which emotion was being depicted – a technique now termed the **judgement method**. He also made careful and insightful observations of those around him. For example, regarding whether the recognition of emotions is innate or learned, Darwin wrote:⁸

'I attended to this point in my first-born, who could not have learnt anything by associating with other children, and I was convinced that he understood a smile and received pleasure from seeing one. ... When a few days over six months old, his nurse pretended to cry, and I saw that his face instantly assumed a melancholy expression, with the corners of the mouth strongly depressed; now this child could rarely have seen any other child crying, and never a grown up person crying, and I should doubt whether at so early an age he could have reasoned on the subject.'

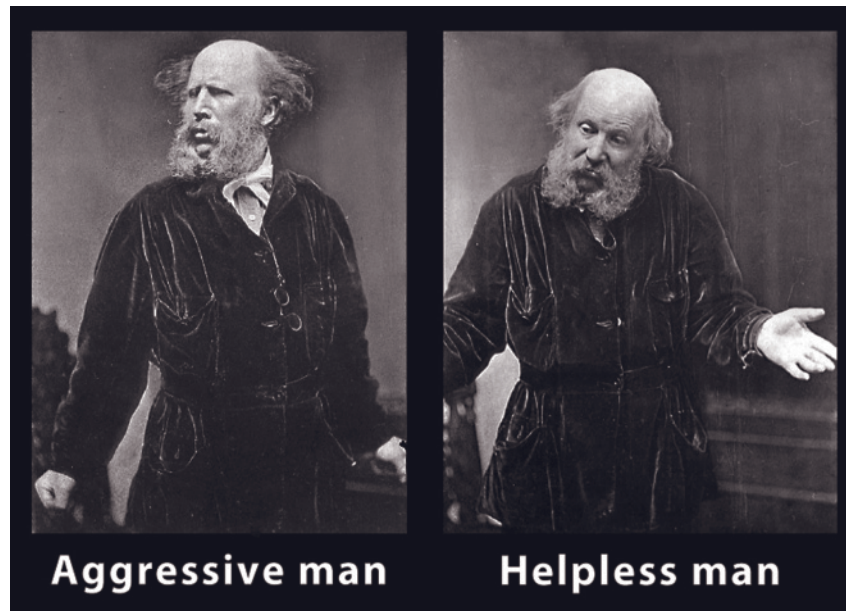


Figure 3.7 Illustration of the expressions of an aggressive and a helpless man (from Darwin, 1872).

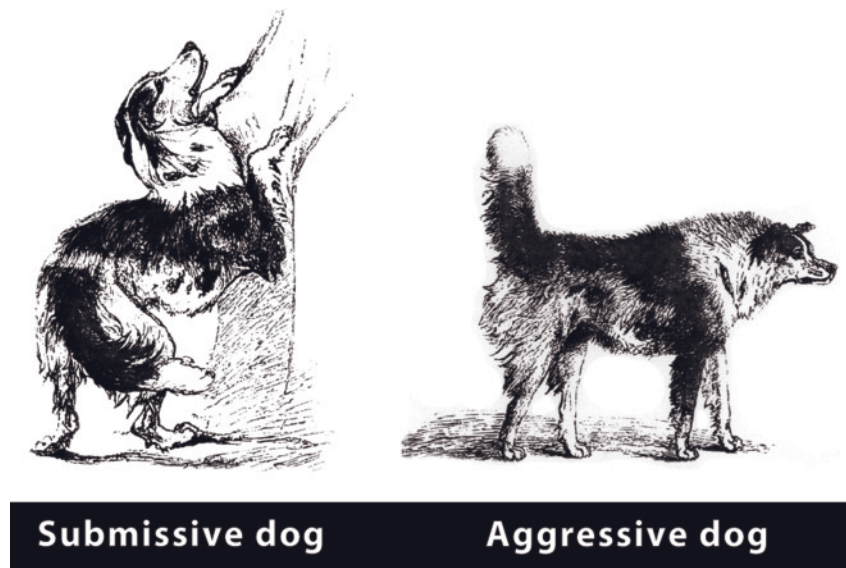


Figure 3.8 Illustration of the expressions of a submissive and an aggressive dog (from Darwin, 1872).

The work of Ekman

Paul Ekman (b. 1934) (Figure 3.9) is a pioneer of the study of facial expressions and their link to emotions and is considered one of the most eminent psychologists of our time. Ekman has admitted that he thought his original research in the 1960s would prove Darwin wrong regarding the universality of facial expressions. However, Ekman found that basic facial expressions of emotion are *not* culturally determined, but universal and thus innate in origin.⁹ Expressions he found to be universal included those indicating **happiness**, **anger**, **fear**, **disgust**, **surprise** and

sadness (Figure 3.10). The findings on the expression of **contempt** are less clear, though there is some preliminary evidence that this emotion and its expression are universally recognized.¹⁰

Ekman devised the list of basic emotions from cross-cultural research on the Fore tribesmen of Papua New Guinea. He observed that members of this culturally isolated tribe could reliably identify the expressions of emotion in photographs of people from cultures with which they were not familiar. They could also ascribe facial expressions to descriptions of situations. On the basis of this evidence he concluded that *some* basic emotions were universal to all humans.⁹

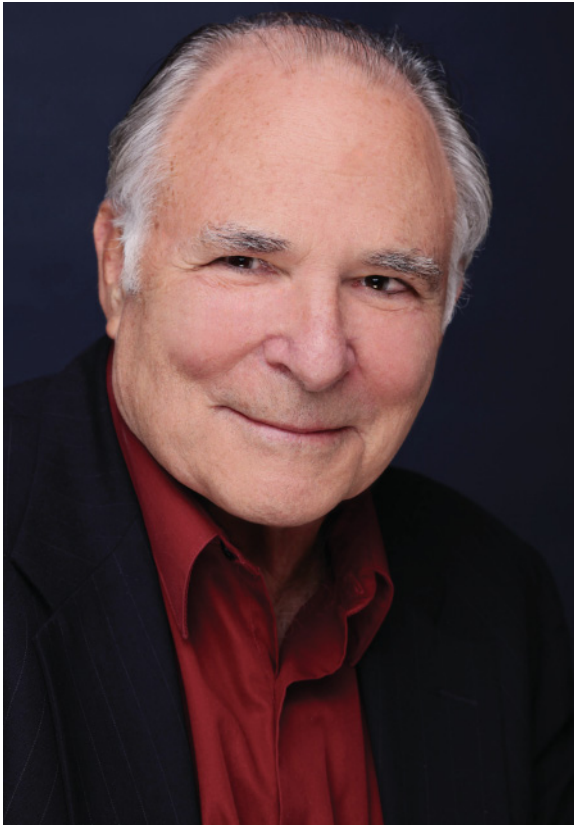


Figure 3.9 Paul Ekman. (Courtesy of Dr Paul Ekman.)

The debate: Are facial expressions of emotion universal or culture-specific?

‘In that brief glance Vronsky had time to notice the suppressed animation, which played over her face and flitted between her sparkling eyes and the slight smile curving her red lips.’

Leo Tolstoy (1828–1910), *Anna Karenina* (1875–77)¹¹

Facial expression is the most important field in the study of non-verbal behaviour. Psychologists have assumed a correspondence between our facial expressions and basic emotions such as fear, anger or happiness. This view has been challenged in recent years. The argument regarding **universality** or **culture specificity** of facial expressions of emotion dates back more than a century. However, there has been a large amount of research in the past 35 years. This is an area of controversy, with proponents on both sides of the fence.⁹

The research on universality has essentially used one main method, with observers being asked to judge the emotion being expressed by a face in a photograph. The evidence has been judged as supporting universality if the observers from different cultures label the expressions with the same terms.

Summary of the evidence

In 1872 **Charles Darwin** published a book entitled *The Expression of the Emotions in Man and Animals*.⁸ Part of the evidence

Darwin presented in support of universality was the answers to a set of 16 questions he sent to Englishmen either living or travelling in diverse parts of the world, including Africa, America, Australia, Borneo, China, India, Malaysia and New Zealand. These observers essentially found the same facial expressions of emotion in each of the peoples studied, which led Darwin to conclude that:⁸

‘the same state of mind is expressed throughout the world with remarkable uniformity ...’

The antagonists to Darwin’s research cited three main problems. Firstly that his sample of observers was too small; secondly that he should have gathered evidence directly from the natives of each country, rather than relying on the Englishmen’s interpretation of their expressions; and finally it is suggested that Darwin suggested the answer he wanted by the way he worded the questions rather than using open questions.

Ekman et al.¹² addressed these concerns and undertook some research to test Darwin’s hypothesis. They enrolled observers from among natives of 21 countries and used open questions. The observers in each culture were shown pictures of actors simulating a facial expression (happiness, anger, fear, sadness, disgust and surprise) and were asked to select one emotion from a list of six to 10 emotion terms, translated into the native language, which corresponded to that expression. For every photograph of facial expression shown, the majority of observers in each country showed agreement regarding the emotion being expressed. Evidence against universality would have been the finding that the expressions the majority of observers in each country judged as showing one emotion were judged as showing another emotion by the majority in another culture, but this was not noted. The only challenge to the methodology used would have been for the observers to be allowed to decide for themselves which emotion was being expressed, rather than having to choose from a given list of emotion terms. Izard,¹³ Boucher and Carlson¹⁴ and Rosenberg and Ekman¹⁵ studied a variety of populations allowing observers to choose their own words in judging the emotion they saw in each facial expression photograph they were shown. In all the studies, the words the observers chose were quite similar, both within and between cultures. They were also similar to the words that had been used in the 1969 Ekman et al. study.¹²

Another argument against universality is that people may have ‘learned’ facial expressions from common sources, such as television programmes and the international media. To answer this question Ekman studied a group in Papua New Guinea in 1967, who had been thus far isolated from the rest of the world.¹⁶ The group had no written language or access to any form of information media. The method Ekman used was first to ask a translator to read to the observer a brief story, and then ask the observer to point to a picture that fitted the story. Ekman found that the observers, who could not have learned expressions from the media, chose the same expressions for each emotion as had the people in the 21 literate cultures previously described. The only exception was that they were unable to distinguish between the faces showing fear and surprise, although they



Figure 3.10 Universal expressions of emotion. (Individual photographs courtesy of Dr Paul Ekman.)

could distinguish these from the other expressions of emotion. Another study by a different team (Heider and Rosch) on a different visually isolated population in West Irian found the same results (reported in Ekman).¹⁷

One of the leading advocates of the culture-specific view of facial expressions was the anthropologist Ray Birdwhistell.¹⁸ He felt that facial expressions and body movement were actually another kind of language. He said, 'I attempted to study the human smile. ... Not only did I find that a number of my subjects "smiled" when they were subjected to what seemed to be a positive environment but some "smiled" in an aversive one.' The main problem with this viewpoint is that Birdwhistell did not consider the possibility that there are different kinds of smiling, which were clearly described many years earlier in the work of Duchenne de Boulogne (1862), the neurologist whom Darwin had quoted extensively.⁶ Duchenne distinguished between the smile of actual enjoyment in which the lip corners are pulled up and the muscles around the eyes are contracted, which Ekman termed the 'Duchenne smile', and non-emotional smiling, which involves just the lip corners rising (Figure 3.11). Ekman later confirmed that there are indeed different forms of smiling.¹⁹

Another challenge to the universality of facial expressions came from an anthropologist, Margaret Mead,²⁰ who said that

the available evidence was all based on judging photographs of posed, not spontaneous, facial expression. Therefore, finding that posed expressions were universal did not necessarily mean that spontaneous expressions were universal. In order to test this a study was carried out comparing the spontaneous facial expressions of American students in California and Japanese students in Tokyo, while they were watching two different films, one neutral and the other stress-inducing.⁹ American and Japanese observers observed the students. It was found that neither the culture of the observer nor the culture of the subject showing the facial expressions mattered in the assessment of the facial expressions that occurred during the neutral or stressful film. In addition, Camras et al.,²¹ who measured American and Japanese infants' facial expressions to arm restraints, found that the infants displayed the same emotional expressions.

There is further evidence to support the link between facial expressions and emotion in terms of human physiology. Electroencephalography (EEG) measures of cerebral activity taken of subjects who were voluntarily making Duchenne and non-Duchenne smiles showed that only the Duchenne smile generated the EEG activity previously found in other studies for positive emotion.²²

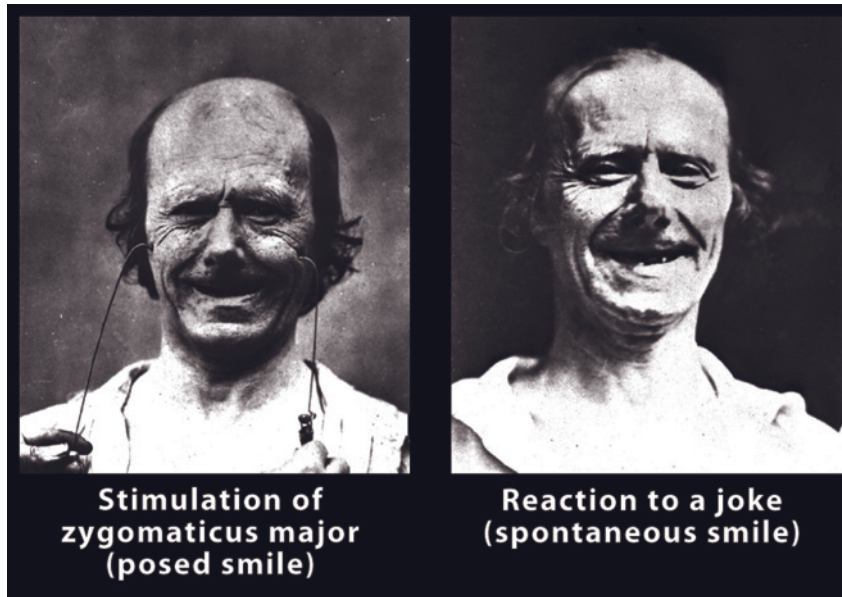


Figure 3.11 Smile types: the posed (non-Duchenne) smile utilizing the zygomaticus major muscles and the spontaneous (Duchenne) smile, which also utilizes the orbicularis oculi ('eye' muscles). (Duchenne's original photographs, from Darwin, 1872.)

Conclusion

It is not known how many different facial expressions are universal for any one emotion, or exactly how many emotions have a universal facial expression. The evidence is strongest for happiness, anger, disgust, fear, surprise and sadness. There is also some evidence that contempt, the emotion related to feeling morally superior to another person, has a universal expression.¹⁰

It seems reasonable to propose that universality in facial expressions of emotion is the connection between particular facial configurations and specific emotions.⁹ This connection between expression and emotion may well have become established due to natural selection.⁸ However, one cannot rule out that some expressions are acquired through species-constant learning.²³

To summarize, the question that seems to be eluding the psychology elite is whether facial expressions are a true reflection of a subject's inner feelings or whether they are just social devices for influencing others? Some psychologists such as Izard¹³ claim the former opinion is true, and others, led by Fridlund,²⁴ claim the latter. Fridlund in fact goes so far as to say that there is no connection between some facial expressions and their respective emotions, i.e. facial expression has much to do with **social communication** but essentially nothing to do with emotion.²⁴ Ekman takes the middle ground, explaining that there is a link between facial expression and emotion. However, it is not a one-to-one relationship as once was thought. Ekman explains that finding universals in expressions does not mean that expressions are not socially influenced.^{9,12,19}

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Chapter 4 Psychological Ramifications of Facial Deformities

‘When, in disgrace with fortune and men’s eyes,
I all alone beweepe my outcast state,
And trouble deaf heaven with my bootless cries,
And look upon myself and curse my fate.’

William Shakespeare, extract from Sonnet XXIX¹

Introduction

The most individualistic, distinguishing physical feature of each person is the face; the representation of self and sense of identity resides to a great extent on facial appearance (Figure 4.1). The importance of facial appearance to normal psychosocial functioning and human happiness cannot be underestimated.

There are three areas where the clinician’s understanding of the underlying psychological constitution of patients is important:

- Improvement of the psychosocial well-being of patients by correcting functional and aesthetic facial deformities – treatment may only be viewed as successful if the patient is happy with the result.
- Recognition of situations where psychological therapy may be required to help the patient adjust, particularly if surgical treatment can only accomplish partial correction.
- Recognition and appropriate management of patients whose main problem is psychological (e.g. body dysmorphic disorder).

Health and psychosocial well-being

In *The Wisdom of Life* (1851) the philosopher Arthur Schopenhauer stressed the importance of health to happiness:²

‘good health is by far the most important element in human happiness.’

The **definition of health** provided by the World Health Organization (WHO), adopted by the International Health Conference in New York in June 1946, was agreed on and signed by the representatives of 61 countries and entered into force on 7 April 1948. This definition has not been amended since 1948:

‘Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.’

The components of health are **physical health** and **mental health** – a concept eloquently described by the Roman writer Juvenal (c. AD 60–140) as ‘a sound mind in a sound body.’³ The focus of healthcare is therefore not only the control of disease processes but the idea that each individual deserves happiness, which in terms of health is termed **health-related quality of life** (Figure 4.2).

If dentofacial and craniofacial surgery are to be categorized, **aesthetic surgery** may be required to gain an *improvement* in *facial appearance*, whereas **reconstructive surgery** is required to improve *function* and *appearance*. (Note: The term **cosmetic surgery** may be better reserved for the treatment of patients requesting a *change* in their appearance, i.e. whose features are within normal limits.) Therefore, one of the primary aims of both aesthetic and reconstructive surgery is to improve the ‘mental and social well-being’ of patients by altering their facial appearance. Functional impairments are an obvious deterrent to health and thereby happiness; nevertheless, patients with facial deformities often cite their facial appearance as their greater concern.

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Figure 4.1 An individual's sense of identity resides to a great extent on their facial appearance. Leonardo da Vinci c. 1501, Royal Library, Windsor. (With kind permission from The Royal Collection © 2010 Her Majesty Queen Elizabeth II.)

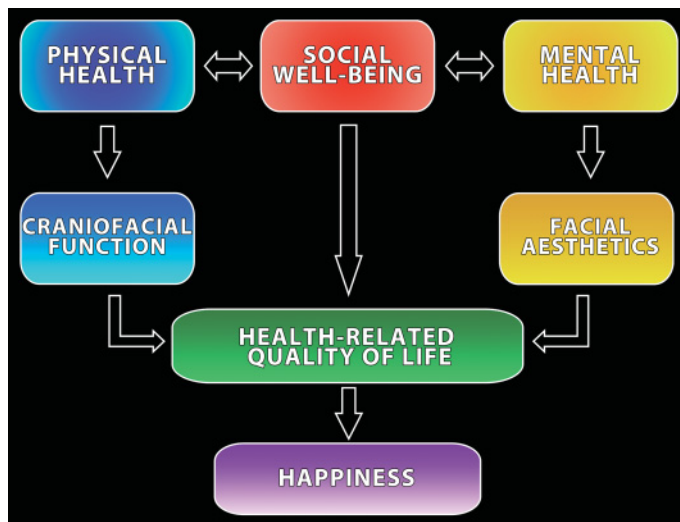


Figure 4.2 Physical health, mental health and social well-being are all necessary requirements for overall health. In terms of the craniofacial region, examples of important functional parameters are visual and auditory, naso-respiratory, mastication, deglutition and phonation. Facial aesthetics is a requirement for mental health. All factors contribute to the health-related quality of life (HRQOL).

Figure 4.3 Draw-A-Person test demonstrating the difference in body image of an 11-year-old child with hemifacial microsomia before (left) and 6 weeks after (right) surgical improvement of the facial asymmetry – the improvement in body image is readily apparent. (Modified from Murray J et al.⁷ with kind permission from Wolters Kluwer Health, © 2010.)

Self-image

‘Nothing has so marked influence on the direction of a man’s mind as his appearance, and not his appearance itself so much as his conviction that it is attractive or unattractive.’

Leo Tolstoy (1828–1910), *Childhood, Boyhood and Youth* (1852–56)⁴

From a very young age, children personify animate and inanimate objects by giving them a face; children’s cartoons follow suit, giving faces to trains, the sun and the moon for children to identify with and understand the object. Stick figure drawings by young children will have a disproportionately large head, eyes and mouth.

In younger children with craniofacial deformities, the **Draw-A-Person test (DAP test)** may be used to shed light on the child’s **self-image**. The test was developed originally by Florence Goodenough⁵ and later revised by Dale Harris.⁶ The child is requested to complete three individual drawings, of a man, a woman and themselves, on separate pieces of paper. No further instructions are given and the child is free to make the drawing in whichever way he or she would like. There is no right or wrong type of drawing, although the child must make a drawing of a whole person each time, i.e. head to feet, not just the face. The test has no time limit, but children rarely take longer than about 10–15 minutes to complete all three drawings. The test is completely non-invasive and non-threatening to children. Murray et al.⁷ demonstrated the difference in **body image** of an 11-year-old child with hemifacial microsomia before and 6 weeks after surgical improvement of the facial asymmetry – the improvement in body image was readily apparent (Figure 4.3).

A person's **self-perception** of their facial appearance is of utmost importance. There is, of course, considerable individual variation in people's abilities to adapt to their facial deformity, whatever the severity, with some individuals remaining comparatively unaffected, while others have significant difficulties affecting their quality of life.

The effect of the response of others on those with facial deformities

'Man's inhumanity to man
Makes countless thousands mourn!'

Robert Burns (1759–96)⁸

The human face has immense social significance, and anxiety about any **visible facial difference** is a **social phenomenon**; it is this *anxiety that may lead to unhappiness*. Facial deformities may be accompanied by functional impairments, which may sometimes be quite considerable. Yet the difficulties of most patients with facial deformities exist almost entirely in the psychosocial ramifications associated with the visibility of their deformity and, in particular, with the response of others to them.

It has even been argued that facial deformity may be a **social disability**, as its impact is not only on the individual affected, but also contributes to the opinions other people form of them.⁹ Although these opinions may well change as interpersonal relationships form, an individual's first impression on others may well affect their own self-esteem and quality of life.¹⁰

Macgregor indicated that facial deformities of a mild to moderate nature may actually cause patients *greater psychological distress* than severe facial deformities.¹¹ This may be because

other people's reactions towards milder deformities are more unpredictable whereas more severe deformities tend to evoke more consistent reactions, albeit negative, allowing the patient to develop better **coping strategies**. The variability in people's reactions to milder facial deformities also results in considerable patient distress. It is important to note that the majority of patients seeking orthodontic treatment or facial aesthetic surgery fit into the mild/moderate category in terms of facial deformity, as opposed to craniofacial malformation syndromes or severe facial trauma/disease.

Teasing and bullying

'He's truly valiant that can wisely suffer
The worst that man can breathe.'

William Shakespeare, *Timon of Athens* (c. 1605)¹²

The difficulties in enduring bullying and teasing are clear and require little elaboration. Children in the school environment can be unsympathetic and hostile to those with visible differences, with teasing and bullying being everyday occurrences (Figure 4.4). The frequency of teasing directed at those with dentofacial differences is significant.¹³ However, empirical evidence suggests that past the initial difficulties, younger children adjust better to those with visible facial differences – the major problems tend to occur from the teenage years onwards into adulthood.

'Sticks and stones may break my bones, but words will never hurt me.' This defiant chant is often taught to children by their parents, to be shouted at school bullies. The implication is that violence may wound a victim but taunting words will not. Unfortunately, this popular proverb is a show of defensive

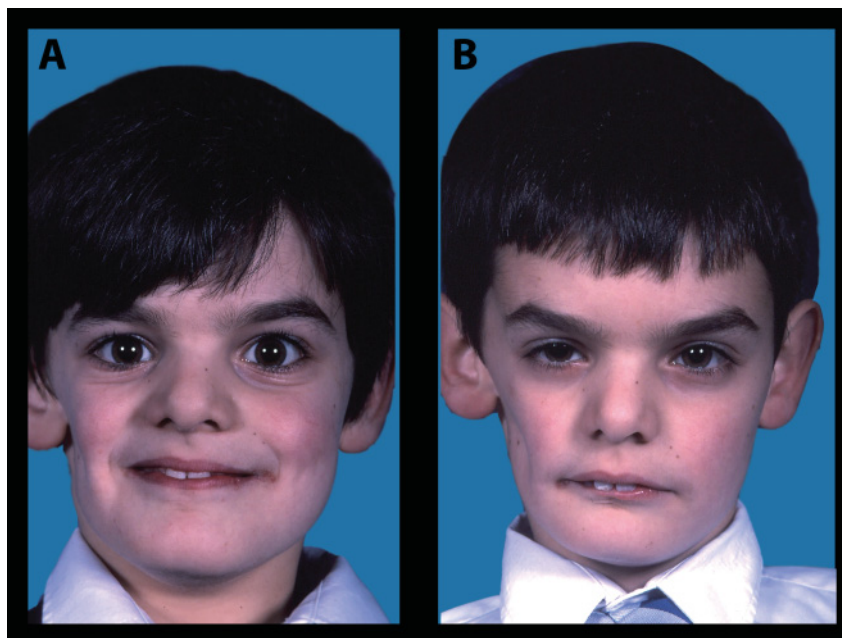


Figure 4.4 Photographs of a patient with hemifacial atrophy taken only 10 months apart – the difference in expression is evident. Teasing and bullying may be exceedingly difficult for anyone to endure.

bravado and its wisdom is unsound; merciless teasing and harsh criticism (critical remarks; verbal humiliation) may not harm physically but certainly leave deep emotional scars. Sir Henry Sidney, in a letter to his son (c. 1560), the English poet Sir Philip Sidney, acknowledged the destructive power of the spoken word:¹⁴

‘A wound given by a word is oftentimes harder to be cured than that which is given with the sword.’

A 13-year-old patient once said: “Sticks and stones may break my bones, but words will never hurt me?” That’s the biggest lie ever told!

To treat or not to treat? The controversial debate

A contentious issue concerns patients presenting with facial anomalies of varying magnitudes and whether they should be treated, especially in situations where the deformity is not part of an active ‘disease’ process.¹⁵ This long-standing and controversial debate regarding the ability to alter facial appearance centres on whether patients with facial deformity should ‘learn to live with’ their facial appearance. The argument for this case states that a psychologically healthy patient should be able to adjust to their social environment. The supporters of this view also state that the education of the public and changes in public attitudes towards all types of visible facial differences is the correct way forward. However, the argument against this case states that the negative effects of facial deformity on the psychosocial well-being of a patient are enough to warrant clinical intervention. The two sides seem unable to find common ground.

However, it may be argued that there is merit in both sides of the argument and that they are in fact *not mutually exclusive*.¹⁵ There is no doubt that attitudes in society towards all types of deformity have changed, and public education is undoubtedly the most important factor here with charities such as **Changing Faces**¹⁶ going a long way in helping to both educate the public and change public opinion regarding facial deformity. Modern society’s media-fuelled obsession with the so-called ‘perfect’ appearance is at best unhelpful and at worst detrimental. Individuals may compare themselves to those who are unrealistically portrayed by the media to represent cultural ideals of beauty, and if their own appearances do not measure up, this may result in body image dissatisfaction, possibly leading to altered self-recognition and conditions such as eating disorders and body dysmorphic disorder.¹⁷ Therefore, although it is unrealistic to expect the media’s obsession with appearance to significantly alter, greater responsibility on the part of the media would be commended. In addition, television documentaries, perhaps interviewing patients and families of patients with dentofacial anomalies, following patients through their daily lives as they describe the challenges they face, would undoubtedly be very useful in terms of education for the general public. Such education may help lessen society’s intolerance for what is considered an ‘abnormal’ facial appearance and may contribute

to transforming the public’s perception of those with facial deformities.

However, it would be simplistic and possibly unethical to withhold treatment on the basis that the problem is with attitudes in society alone.¹⁵ *It is very difficult to judge someone’s decision to have treatment unless one has lived a similar life and has some awareness of their experiences.* If treatment is available that can significantly improve a patient’s quality of life, then it is for the patient to make the ultimate informed decision of whether treatment is the correct way forward for them.

Body dysmorphic disorder: the delusion of deformity

Pablo Picasso (1881–1973) is well known as one of the greatest and most influential artists of the twentieth century, making arguably the most significant contribution to the development of modern art in that century, with virtually no artist escaping his influence. His works did not have the purpose of reproducing what we see, but were designed ‘to make us see’.

A portrait may represent a subject in many different ways. It can be a literal representation or it can represent a person symbolically. It can capture a person’s physical characteristics and/or attempt to represent their emotions or personality. Picasso was 51 years old when he painted the *Girl Before a Mirror* (Figure 4.5), which portrays a young woman surveying herself in an oval mirror. The woman in this painting is Marie-Therese Walter, one of Picasso’s girlfriends, with whom he lived and had a child, Maya. In this portrait she is examining and inspecting her appearance in a mirror, but Marie-Therese and her reflection are not identical.¹⁸ Art critics have suggested that this represents a symbolic duality, that is, two different sides of her character. However, closer scrutiny of this painting indicates a woman who sees herself in a distorted way, which resembles what in clinical psychology is termed **altered self-recognition**.

Picasso often experimented by showing multiple views of an object on the same canvas to convey more information than could be contained in a single, limited view. For example, he has drawn the face of Marie-Therese in two halves, which enhance one another, a frontal and profile view. The expression on the face of Marie-Therese unveils a distinct sadness at the image she sees staring back at her in the mirror. In the distorted reflection she sees her nose as long, while the lower third of her face is vertically shortened and retrusive. Her almond shaped eye is seen as a large ellipsoidal rectangle, with the sclera missing. She sees the reflection of her smooth olive skin as blemished chalky lilac in colour. The left side of her forehead, upper third of her face and nose reflect a substantial scarlet stain, resembling a port-wine stain. Her full blond hair is reflected as thin and green. In her reflection she observes vertical asymmetry in the position of her breasts, which appear scarred. She sees herself not the way she looks but as a visual fallacy. *Her mind has deformed her face and body*.¹⁸

The majority of clinicians involved in the management of patients with facial deformities will encounter the patient who

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Figure 4.5 *Girl Before a Mirror*, Pablo Picasso, 1932, oil on canvas. The Museum of Modern Art, New York, NY. Gift of Mrs Simon Guggenheim. (With kind permission © 2006 Succession Picasso/DACS, London 2010.)

is excessively concerned with a minor or imperceptible defect in their appearance, or patients who show extreme dissatisfaction despite good treatment results. Patients with such a preoccupation with appearance that causes them significant distress in their social or occupational functioning may have ‘non-delusional dysmorphophobia’, also known as **body dysmorphic disorder (BDD)**.^{19,20}

Body dysmorphic disorder

The Italian professor of psychiatry **Enrico Morselli** (Figure 4.6) described a condition termed ‘dysmorphophobia’ in 1891. The condition has been redefined as two separate entities: delusional and non-delusional variants. It is only relatively recently that the non-delusional variant has been classified as BDD in the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV)*.²¹

BDD is characterized by a preoccupation with an *insignificant or non-existent appearance defect* that causes *significant distress* to the patient and *interferes with their social life*. The most common preoccupations involve the skin, nose, eyes and eyelids, lips, mouth, jaws and chin. However, any part of the body may be involved and the preoccupation may involve several body parts simultaneously.²² The American Psychiatric Association



Figure 4.6 The Italian professor of psychiatry Enrico Morselli (1852–1929) coined the diagnostic category of ‘dysmorphophobia’ in 1891, although he made reference to an earlier paper from 1886 in which he began to discuss the concept. The term was introduced into English with the publication of Eugenio Tanzi’s book in 1910.

DSM-IV (1994) **criteria required to make a diagnosis of BDD** are as follows:²¹

1. There is a preoccupation with an imagined or minimal defect in appearance. If the defect is minimal, the individual’s concern is excessive.
2. The preoccupation causes substantial emotional distress and impaired social and occupational functioning.
3. The preoccupation is not caused by other mental disorders.

Although the perceived physical anomaly may concern any part of the body, the face is commonly involved. Patients may have specific or vague concerns. The preoccupation with a particular feature may remain unchanged or their complaints may shift from one body part to another over time. Although a patient’s insight into the severity of their concerns is variable, they are often deeply convinced of the severity of their defect. It is not possible for a clinician to simply talk the patient out of their concern.

BDD usually commences in adolescence, with a gradual onset.²³ However, sudden onset may also occur, particularly following major life events, such as the termination of a relationship or leaving home.²⁴ Mild symptoms in adolescence may subside over time, but moderate to severe symptoms tend to

follow a more chronic path. There is frequent **comorbidity** in patients with BDD, particularly associated with:²⁵

- Depression.
- Social phobia.
- Substance abuse.
- Obsessive compulsive disorder (OCD).
- Eating disorders.

Note

The dentist is likely to be the first clinician to observe the characteristic **dental erosive pattern** due to vomiting in patients with eating disorders. Regurgitation erosion, caused by the regurgitation of hydrochloric acid from the stomach, commonly affects the palatal surface of the maxillary anterior teeth and the occlusal and buccal surfaces of the mandibular posterior teeth.

The nature of BDD is such that it very much takes hold of the patient's life. Significant social problems, including social isolation and work-related problems due to avoidance of social interaction, result from a conviction that those around them consistently notice their 'defect'. Up to 50% of BDD patients admit to suicidal ideation.²⁶ There is insufficient data on the prevalence of BDD and the condition is likely to be underdiagnosed and underrepresented due to the secrecy of those affected. Figures from 0.7% to over 5% have been estimated, with an equal sex incidence.²⁷ However, the prevalence among patients seeking facial aesthetic treatment may well be higher.²⁸ The prevalence in cosmetic surgery and dermatology clinics has been found to be 5% and 12%, respectively.²⁹ People with BDD are often single or separated.

Diagnosis

The diagnosis of BDD is vital for any clinician involved in any form of dentofacial or craniofacial appearance altering treatment. Timely diagnosis will initiate appropriate referral to mental healthcare professionals. An increasing number of specialist craniofacial hospital units now employ a **clinical psychologist** or **liaison psychiatrist** with expertise in this field. This will ultimately avoid much stress for the patient and the clinician, and help to avoid possible future medicolegal issues.

Diagnosis is essentially based on the patient interview, past medical history and observation of recognized patterns of behaviour (Table 4.1). There is no single question that will disclose a diagnosis of BDD. The patient will initially be asked an open question regarding the reason for their consultation and their concerns. Patients with BDD are likely to have excessive concerns about a minor or imperceptible defect in their appearance. They may be over-specific about a perceived appearance flaw, but may also sometimes be rather vague in their description of a defect. In addition, a history of 'doctor shopping', dissatisfaction with previous clinicians and treatment, and unusually

Table 4.1 Indications and 'giveaway' signs of body dysmorphic disorder

Patient interview/consultation:
• Excessive concerns regarding a minor or imperceptible appearance defect • Over-specific concerns, often with the patient bringing diagrams and pictures to demonstrate how they should be treated • Vague description of concerns (as opposed to over-specific) • Patient admits to chronic mirror checking behaviour • Dissatisfaction with previous clinician(s)/clinical treatment • 'Doctor shopping', particularly if previous clinicians have refused to undertake treatment • Illogical desires, such as that a clinical procedure will change their life, job prospects or personal relationships • Unrealistic expectations of clinical treatment result
Past medical history:
• Previous history of psychiatric treatment, particularly for depression • Anxiety disorders, particularly obsessive-compulsive disorder (OCD) and social phobia (avoiding social situations, even being housebound) • History of substance abuse • History of eating disorders
Social and family history:
• Unemployed • Unmarried/divorced and/or living alone • Family support: does the patient have a poor relationship with their family?
Recognized patterns of behaviour:
• Unusually demanding or suspicious behaviour • Frequent cancellation and rebooking of appointments • Camouflaging behaviour, such as covering the mouth with a hand or scarf

(Modified from Naini and Gill²⁹.)

demanding behaviour are 'red flag' signs. It is possible that the patient may hide any previous psychiatric history from the clinician for fear that it will prevent them from receiving treatment. Another factor is whether the patient blames their 'defect' for lack of success in life, work or personal relationships. Such patients are likely to have unrealistic expectations that treatment will solve all their problems. It is important to ask the patient how much time they spend thinking about their defect, and also

how long they spend looking in a mirror per day. Engaging in any such compulsive appearance-related behaviour for more than an hour a day is a cause for concern.²⁰ Patients may also use camouflaging techniques, such as covering their mouth with their hand or a scarf. Frequent cancellation and rebooking of appointments and a suspicious attitude should also alert the clinician.

Informing the patient

The patient should be informed that surgical treatment alone will not be beneficial for them in the long term. It is important to do this without offending them. It is also vital for the clinician not to allow the patient to talk them into providing treatment. The patient may be informed in a polite and straightforward manner, and the clinician should stress the fact that they are acting in the best interests of the patient. After obtaining the patient's consent, subsequent referral to a clinical psychologist or psychiatrist is the required course of action.

Management

BDD is a psychiatric disorder. Therefore, any form of surgical treatment is likely to leave the patient unhappy, often more so than before treatment was instigated. Patients often find fault in the treatment result, and may find new 'defects'. There are situations when treatment may be provided when a minor defect actually exists, but this must be undertaken *jointly* with the support of a clinical psychologist or psychiatrist. Therefore, the overall recommendation is not to undertake surgical treatment on patients with BDD.³⁰

People diagnosed with BDD should be treated by a clinical psychologist or psychiatrist with experience in managing the disorder. Having confirmed the diagnosis, treatment may be undertaken by **psychotherapy**, **pharmacotherapy** or a **combination** of the two. **Cognitive-behavioural therapy** in particular has been shown to be effective in the management of BDD. Two methods of cognitive-behavioural therapy specifically have demonstrated beneficial results:

- **Exposure therapy:** This deals with the patient's ability to 'expose the defect' in a social setting.
- **Response prevention:** These are techniques to prevent the patient from using established behaviour patterns, such as mirror checking and camouflaging behaviour.³¹

Pharmacotherapy may also be effective in the management of BDD. Selective serotonin reuptake inhibitors are currently the first-line medication, helping to reduce obsessive-compulsive behaviour.³²

Clinical intervention, without the support of a clinical psychologist or psychiatrist will often exacerbate a patient's symptoms and lead to greater problems. The challenge for clinicians is therefore to *diagnose the condition prior to instigating clinical treatment*.

In severe BDD cases, patients experience self-inflicted mental torture and anguish. Without appropriate diagnosis and psychiatric management these patients are condemned to a life of distress and misery, held captive by the stigma of a perceived

deformity. It is interesting that with his painting *Girl Before a Mirror* Picasso gave form to the terror that such individuals experience, capturing the patient's torment in a work of art that will last an eternity.¹⁸

Conclusion

'O why was I born with a different face?'

William Blake (1757–1827), from the poem 'Mary', the *Pickering Manuscript* (c. 1803)³³

It is appropriate that this chapter concludes with a short account of Professor **Frances Cooke Macgregor** (1906–2001), the renowned social scientist and scholar whose research and writing on the psychosocial significance of visible facial differences was the first acknowledgement of disfigurement as a disability (Figure 4.7). Her publications documented 40 years of research.

Macgregor's work on facial disfigurement began during the Second World War while photographing patients at the Ellis Fischel Cancer State Hospital in Columbia, Missouri. Shortly after the war, she met plastic surgeon Dr John Marquis Converse, who helped repair the shattered and burned faces of English and French pilots. His specialty coincided with her interest in the social and psychological ramifications of facial disfigurement. Converse supported Macgregor's suggestion to conduct an exploratory



Figure 4.7 Frances Cooke Macgregor (1906–2001).

study of his patients at a time when the existing literature on physical disabilities was limited almost entirely to functional impairments. Macgregor's work eventually led to the addition of facial disfigurement by the WHO to its list of disabilities. In 1951 the Society for the Rehabilitation of the Facially Disfigured was established, now known as the National Foundation for Facial Reconstruction (NFFR). When she was honoured with a Special Citation for Distinguished Service from the Society for the Facially Disfigured, Macgregor said:

'Now is not the moment for complacency or self-congratulation. There is still a great deal to be done. There are thousands and thousands of men, women and children in this world like those you see today who, only because of the way they look, are among the least accepted in our society and the most neglected.'

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PART II

CLINICAL DIAGNOSIS

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SECTION 1 Patient Interview and Clinical Diagnostic Records

Introduction to Section 1

‘Diagnosis precedes treatment’

Ibn Sina (Avicenna) (AD 980–1037), Persian physician-scholar, *Canon Medicinae* (*The Canon of Medicine*)

Diagnosis

The term diagnosis is perhaps the most important throughout medicine. It derives from the Latin *diagnōsis*, from Ancient Greek *diagnōsis*, from *diagignōskein* (‘to discern’), from *diá* (split-‘apart’) and *gignōskein* (‘to learn’). Accurate clinical diagnosis requires the clinician to obtain relevant data using observation, hearing and palpation.

In the management of craniofacial and dentofacial deformity **clinical diagnosis** is made through the **acquisition and analysis of data** obtained through three stages:

- **History** – data obtained by patient interview.
- **Clinical evaluation** – data obtained by physical examination of the patient.
- **Investigations** – data obtained by analysis of relevant diagnostic records.

The acquisition of relevant data in each step requires a *thorough, accurate and systematic approach* from the clinician. In most aspects of medicine the patient history is arguably the most important step. Experienced physicians, in particular, often use the physical examination and the results of diagnostic tests to confirm their initial diagnosis from the patient history. However, in the management of facial deformities, the purpose of the patient history is to find out the *suitability* of the patient for

treatment. Once the general health and psychosocial condition of the patient are deemed suitable for treatment, and the clinician is convinced that such *treatment is in the best interest of the patient*, the greater part of the data required for accurate diagnosis is obtained from the physical examination of the patient and analysis of diagnostic records.

Terms of direction, position and movement

Descriptions of the craniofacial complex are based on three imaginary **planes** (Figure S1.1):

- Sagittal (anteroposterior) plane.
- Coronal (frontal) plane.
- Transverse (horizontal) plane.

The **midsagittal** (or median sagittal) plane passes longitudinally through the head and divides it into right and left halves. Sagittal planes parallel to the midsagittal plane through the left and right halves of the craniofacial complex are termed **parasagittal** planes.

The structural relationships, or movement, of the component parts of the craniofacial complex may also be described in relation to the **three axes of rotation** (Figure S1.2):

- Sagittal (anteroposterior) axis.
- Vertical (longitudinal) axis.
- Transverse axis.

These descriptive terms are required to designate the position of regions of the craniofacial complex in space and in relation to each other.

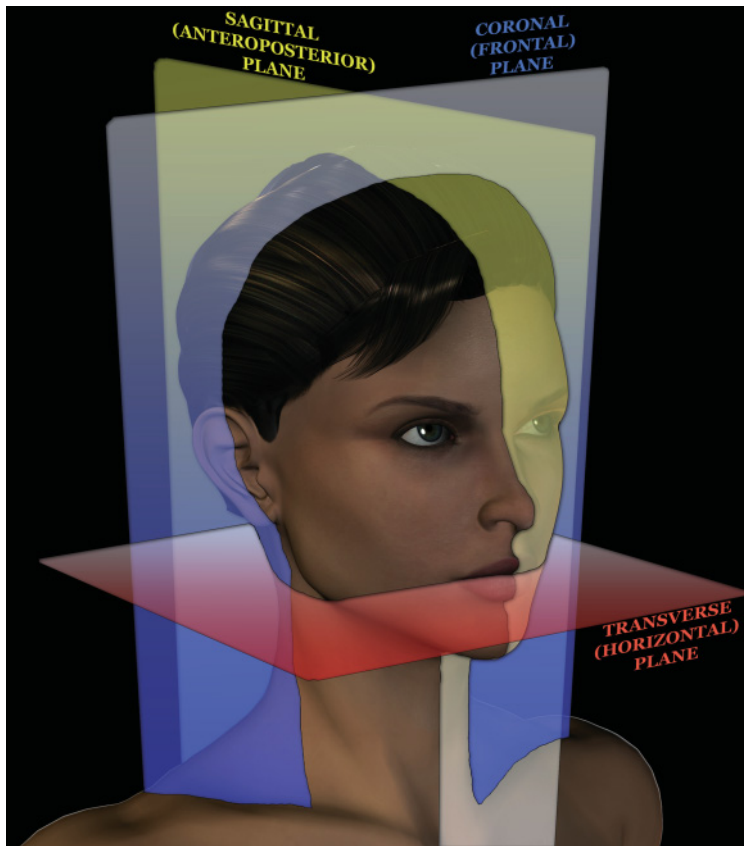


Figure S1.1 The facial planes.

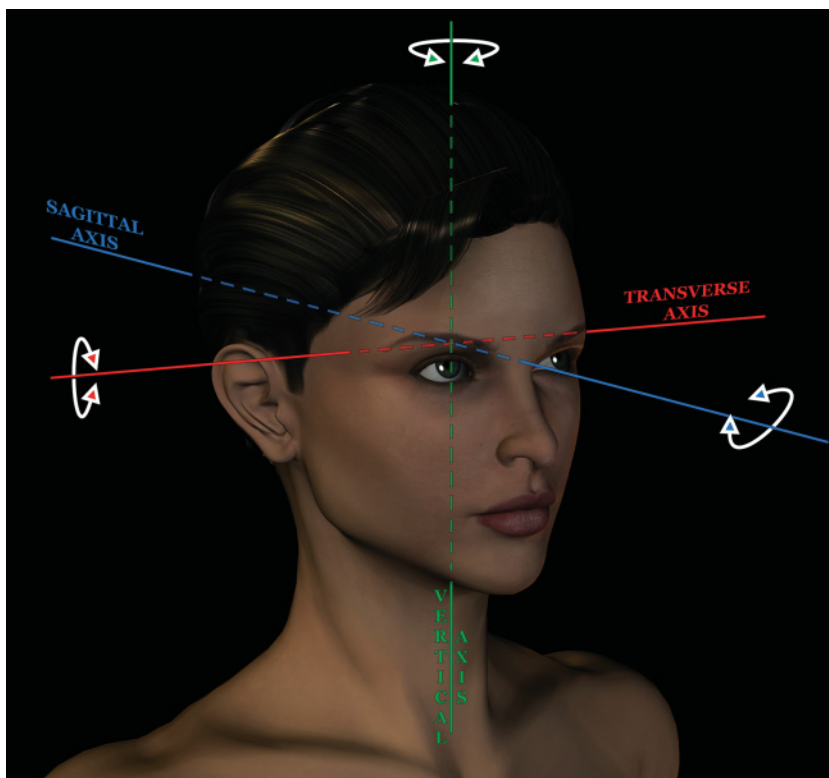


Figure S1.2 The axes of rotation.

Chapter 5 Patient Interview and Consultation

‘Time spent in communication (with patients)
is never wasted’

Frances Cooke Macgregor (1906–2001)¹

Introduction

The first step to clinical diagnosis is the information obtained from the patient interview. The patient interview is often the first contact between the patient and clinician and any breakdown in communication at this stage may be irreparable. The clinician’s approach should be courteous and professional, but not over-familiar. The purpose is to establish effective communication and gain the trust of the patient in order to obtain the required information. Scully says, ‘The patient will know if you care, well before they care if you know.’²

The patient interview should be a well-organized, **structured conversation**, i.e. the clinician should direct the interview but the patient should be allowed to communicate their feelings and apprehensions to the clinician. The clinician will thereby gain insight into the patient’s aesthetic and/or functional *concerns* and, more importantly, their *attitude* towards it. The patient should be sitting comfortably at the clinician’s eye level and the initial interview/consultation should be, as far as possible, free from interruption.

Presenting complaint

The patient’s **presenting complaint**, as always, is very important. However, clinicians must be aware that a patient presenting

for an initial consultation may have numerous mixed emotions and will often find it difficult to convey their reasons for seeking advice or treatment. Therefore jumping in with the type of treatment that is required may well frighten the patient.

The patient should be encouraged to speak freely and honestly using their own words, although the clinician will often need to *gently guide* the interview. **Leading questions**, i.e. those which suggest the answer, should be avoided. **Open questions**, which do not suggest an answer, are preferable. It is far better to ask a patient what concerns they have rather than if the prominence of their chin is their main concern. **Closed questions**, which usually have a ‘yes or no’ answer, may occasionally be used *during* the interview to extract specific information, particularly in patients with rather vague concerns.

The clinician should demonstrate **attentive listening** by maintaining eye contact with the patient, occasionally nodding and making reassuring remarks such as ‘I understand’ and ‘Please continue’. It is also important to avoid medical jargon and always use language that the patient can understand. It is likely that the clinician’s body language and **non-verbal communication** will dominate the patient interview. Psychologists claim that the majority of face-to-face communication is non-verbal; the clinician’s body language and tone of voice are as important if not more important than the actual words used (see ‘Mehrabian’s rule’, Chapter 3).^{3,4} *Clinicians must never be, or appear to be, indifferent, unsympathetic or judgemental to a patient’s concerns.*

Note

Five Chinese characters make up the word 'listen'. The largest character by far is 'ear', which denotes not just 'hearing', but actually 'listening to' the patient. The other four characters are: 'you', 'eyes' (denoting looking at the patient), 'undivided attention', and 'heart' (denoting 'empathy', which literally means 'stepping into the patient's shoes').

The concerns of patients with facial deformities are likely to be either aesthetic, functional or a combination of both. Clinicians should be aware that patients may sometimes play down their aesthetic concerns initially, sometimes due to concerns that 'aesthetic' problems may not be covered by health service hospitals/insurance schemes or simply because they feel embarrassed. Informing the patient that the primary reason most patients seek dentofacial/craniofacial treatment is aesthetic may be helpful.

History of presenting complaint

In patients with facial deformities the main question is, 'Why did the patient decide to have the problem corrected *now*?' The duration of a patient's concern with a facial deformity is significant as an indicator of their genuine motivation for treatment. A patient who decided only recently to have treatment, particularly if the decision has been due to a life alteration such as, for example, unemployment or divorce, is likely to be unhappy with the results of treatment.

Psychosocial history

The majority of patients undergoing treatment to correct dentofacial deformities will be happy with the results of treatment. Post-treatment dissatisfaction often stems from lack of communication between the clinician and patient or as a result of a psychological and/or emotional disturbance in the patient, *unidentified* at the initial patient interview stage.

The clinician will often require more than one consultation appointment in order to evaluate the following:

- **Perception:** The **patient's perception** of their dentofacial appearance is vitally important. The clinician's first goal is to determine whether a facial deformity exists and if so, whether *the patient's perception of the deformity ties in with the clinician's evaluation*. If a patient has excessive concerns regarding a minor or imperceptible facial deformity, has seen a number of other clinicians and treatment has been refused, or if they are particularly vague about their concerns, then referral to a clinical psychologist or liaison psychiatrist may be required, as these signs may suggest evidence of a psychiatric disorder, such as **body dysmorphic disorder** (BDD). A study by Phillips et al.⁵ of patients with dentofacial deformity requiring orthognathic surgery found that almost a quarter

of the patients qualified as a positive diagnosis for psychiatric disorder.

- **Motivation:** The patient's motivation for seeking or undergoing treatment is important. Patients who have **external (extrinsic) motivation**, involving for example the desire to please others or have a more successful career, are less likely to be happy with the results of treatment than patients who have **internal (intrinsic) motivation**, which is that they want to look better for themselves.
- **Expectation(s):** It is important for patients to have realistic expectations. A desire to look like their favourite film star is often neither realistic nor achievable. The affect of any facial deformity on a patient's **personality** is paramount. Socially well-adjusted patients with stable lives, e.g. working, married, tend to benefit from treatment whereas unstable, socially poorly adjusted patients with **unrealistic expectations** will inevitably be unhappy with the results of treatment. It is also *vital for the clinician not to over-promise*. The patient must fully understand:
 - The likely result that can be *realistically* achieved: e.g. patients with facial asymmetries must comprehend that their post-operative result will never be perfectly symmetrical.
 - The approximate *length of treatment*.
 - The likely *complications*.

Only in this way will they be able to make an **informed decision** about proceeding or not with treatment.

- **Cooperation:** The clinician must attempt to gauge the likely level of cooperation.⁶ Prolonged treatment, such as combined orthognathic treatment, may require treatment for a number of years and, as such, require considerable commitment from the patient. Patients must be made aware of the **risk/cost-benefit considerations** of any proposed treatment strategy. Proffit⁷ refers to such 'risks/costs' in a broader sense as the **burden of treatment**.
- **Support network:** The patient's **social support network** must not be underestimated, particularly **family support**. It is important for the clinician to meet and gauge the support of the immediate family as anything other than full support from a spouse or parents may lead to considerable difficulties. Any criticism of the results of treatment by a family member, which may occur if the individual did not want the patient to have treatment, may quite easily lead to an unhappy and even depressed patient.

Medical history

A thorough medical history must always be taken. The use of a standardized, self-administered questionnaire may be helpful in encouraging more truthful responses to sensitive questions. It is helpful for the patient to complete such a questionnaire prior to the consultation and for the clinician to verbally double-check the responses at the end of the consultation when rapport has been built.

In patients with facial deformities, particularly relevant aspects of medical history are past or present **psychological or psychiatric illness, anxiety and depression** or any **body image disturbances** such as anorexia or bulimia nervosa.

Note

At the end of the consultation it is useful to ask the patient if they have *any further questions*. This is because patients are often anxious and sometimes may even feel rather intimidated by their surroundings and the occasion, particularly if there are trainees observing the consultation in a hospital environment; they may have further questions but may feel uneasy about asking.

It is imperative that thorough, contemporaneous *written* records of the patient interview are kept.

Danger signals and the 'problem' patient

Treatment of a 'problem' patient will lead to difficulties for the clinician in the short and long term, but is also disastrous for the patient. Sir William Osler wrote: 'It is equally important to make the patient happy as it is to make him well.'⁸ Refusing to treat a patient demonstrating rude, arrogant or aggressive behaviour towards the clinician or staff may be uncomfortable but is certainly preferable to the long-term agony of taking them on. Other patients may benefit from treatment but require psychological or psychiatric support.⁹ As explained in Chapter 4, it is important to inform such patients without offending them. It is also vital for the clinician not to allow the patient to talk them into providing treatment. The patient may be informed in a polite and straightforward manner, and the clinician should stress the fact that they are acting in the best interests of the patient.

Clinicians should be wary of any characteristics that may signify a potential 'problem' patient:

- Body image disturbances:
 - The patient excessively concerned with a minimal or imagined deformity (a possible sign of BDD).
 - A history of anorexia or bulimia nervosa.
- Poor and/or external motivation.
- Unrealistic expectations.
- Lack of family support or familial disapproval.
- Uncooperative patients.
- Vague concerns: the patient should have a clearly discernible problem and an understandable, though not neurotic, concern.
- Rude or aggressive behaviour (towards clinician or other members of staff).

Tardy et al.¹⁰ (1995) have described a number of other 'red flag' or 'danger signals':

- The indecisive patient: It is not appropriate for patients to want the clinician to make up their mind for them. In such situations the clinician should simply say: 'My role is to give you as much information as you need in order for you to make the correct decision *for you*.' Clinicians should never talk patients into having treatment. Aristotle (384–322 BC) wrote: 'It is no part of a physician's work to use either persuasion or compulsion upon the patients.'¹¹
- The obsessive-compulsive or perfectionist patient.
- The self-appointed 'VIP' patient.
- Over flattering patients.
- Overly familiar patients.
- The surgeon shopper.
- The 'plastic surgiholic'.
- Patients involved in litigation.

The young male rhinoplasty patient is often described by plastic surgeons as a danger signal requiring in-depth preoperative interview and psychosocial evaluation.¹² The characteristics of such an individual and the likelihood of dissatisfaction with the post-operative result have been formed by plastic surgeons into a well-known acronym, 'SIMON': Single, Immature, Male, Over-expectant and Narcissistic.

Note

So long as no major 'red flag' signs are noted by the clinician, arrangement may be made for obtaining any necessary diagnostic records and a second consultation. Information leaflets may be given and the patient should be asked to write down and bring any further questions with them to the following consultation. A reasonable time between the initial and second interview is useful, permitting a period of contemplation for the patient.

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Chapter 6 Clinical Diagnostic Records, Natural Head Position and Craniofacial Anthropometry

Introduction

The purpose of this chapter is to provide the information regarding the required diagnostic records and techniques necessary for facial aesthetic analysis.

Clinical diagnostic records

Accurate diagnostic records are an important supplemental tool to clinical patient evaluation in the diagnosis of craniofacial deformities. The purposes of clinical records are:

- **Diagnosis:** To provide *additional data* to the clinical evaluation, particularly regarding the structural relationship of the dentoskeletal complex to the overlying facial soft tissue drape.
- **Treatment planning:** The preliminary records may be used as an aid to treatment planning; this is particularly useful in cases where more than one treatment option is available, permitting the simulation of treatment alternatives. Presurgical records are fundamental for accurate surgical planning.
- **Treatment analysis:** End of treatment records may be compared with previous records in order to analyse the success of treatment and permit improvement for future patients.
- **Patient communication:** Visual records may be used to explain clinical procedures or alternative treatment plans.
- **Teaching, research and audit.**
- **Medicolegal documents.**

Note

A general guideline to follow in clinical evaluation is that *clinical observation is more important than the data obtained from diagnostic records*. Diagnostic records are required to verify the results of the clinical evaluation and to provide more detailed information regarding underlying structural relationships. Therefore, if the results of the clinical evaluation and the diagnostic records are at odds, the *patient must be evaluated further* to resolve the inconsistency.

The diagnostic records that may be required are discussed below.

Radiographs

Radiographic images form arguably the most important diagnostic records in craniofacial evaluation. The most commonly used radiographic techniques are:

- Rotational tomography.
- Cephalometric radiography.

The **rotational tomograph** is alternatively termed the **orthopantomograph** (OPT or OPG) or **dental panoramic tomograph** (DPT) (Figure 6.1). The OPT is required for:

- Assessment of dental development.
- Evaluation of mandibular asymmetry.

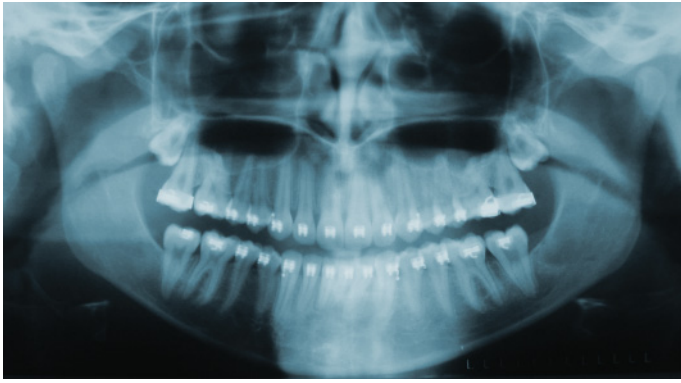


Figure 6.1 Orthopantomograph (OPT or OPG), alternatively termed a dental panoramic tomograph (DPT).

Note In the presence of fixed orthodontic appliances, it is useful to remove the archwires prior to taking any presurgical radiographs.

- Evaluation of the relationship of the inferior alveolar nerve to the mandibular third molars.
- Localization of impacted, ectopic or supernumerary teeth.
- Assessment of root lengths.
- Assessment of general and/or dental pathology.

The **lateral cephalometric radiograph** is a vitally important diagnostic tool. In 1931, B Holly Broadbent in the USA and Herbert Hofrath in Germany, independently of one another, developed a system of skull radiography with a head-holding device termed a **cephalometer**, or **cephalostat**, which was used to obtain *standardized* and *reproducible* craniofacial images on radiographic film (Figure 6.2). The diagnostic uses of the lateral cephalometric radiograph include:

- **Diagnosis and treatment planning.**
- **Monitoring craniofacial growth:** The **superimposition** of standardized, reproducible **serial cephalometric radiographs** provides an indication of the direction of jaw growth and may be used to assess the cessation of the pubertal growth spurt.
- **Monitoring treatment changes:** Comparison of linear and angular cephalometric measurements from serial radiographs provides a useful indication of treatment changes. Incisor decompensation (see Chapter 22) in the sagittal and vertical planes, in preparation for orthognathic surgery, may be evaluated.
- **Estimation of skeletal age:** Some authorities rely on **cervical vertebral maturation** to determine skeletal age by assessment of the pattern of bone ossification. Unfortunately, as with **hand-wrist radiographs**, the possible error in this method cannot yet permit undue reliance on this technique.
- **Localization of unerupted teeth:** The radiograph may assist in the confirmation of the buccopalatal position of unerupted maxillary canines.
- **Teaching, research and audit.**



Figure 6.2 Lateral cephalometric radiograph; the opacity of the head-holding ear rods is evident.

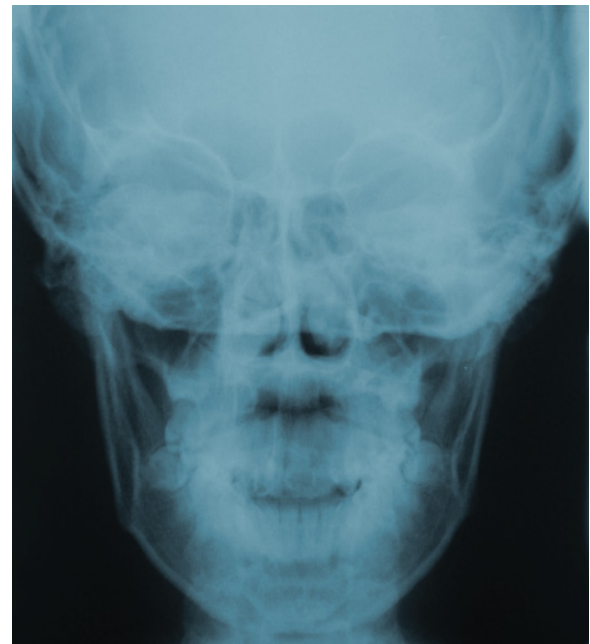


Figure 6.3 Posteroanterior (PA) cephalometric radiograph.

The **posteroanterior (PA) cephalometric radiograph** may be required in the evaluation of **facial asymmetry**, forming an important adjunct for qualitative and quantitative dentoskeletal evaluation (Figure 6.3).



Figure 6.4 Dental study casts.

Clinical photographs

Extraoral and intraoral colour photographs are required at the start, often during and at the completion of treatment. They are used for:

- Diagnosis and treatment planning.
- Monitoring growth: The photographs should be standardized and may be taken with the patient in a cephalometer-type set-up equipped with ear rods.
- Monitoring treatment progress.
- Patient communication.
- Teaching, research and audit.
- Medicolegal documentation.

Study models

Study models, or dental study casts, are required in all patients with dental-occlusal anomalies and those requiring craniofacial surgery that will involve movement of the jaws. The initial impressions should be fully extended into the labial and buccal sulci and record all the erupted teeth. The models are trimmed in a special way (**Angle's trimmed**) so that the bases are symmetrical, enabling the occlusion to be evaluated at varying angles with the models placed on a flat surface and making it easier to analyse arch form and arch symmetry (Figure 6.4). The study models should be mounted onto an **adjustable articulator** (a mechanical device that represents the temporomandibular joints, to which the maxillary and mandibular casts may be attached, with the intention of reproducing mandibular movements), using a **facebow transfer** (a facebow is a device used to record the relationship of the maxillary dental arch to the

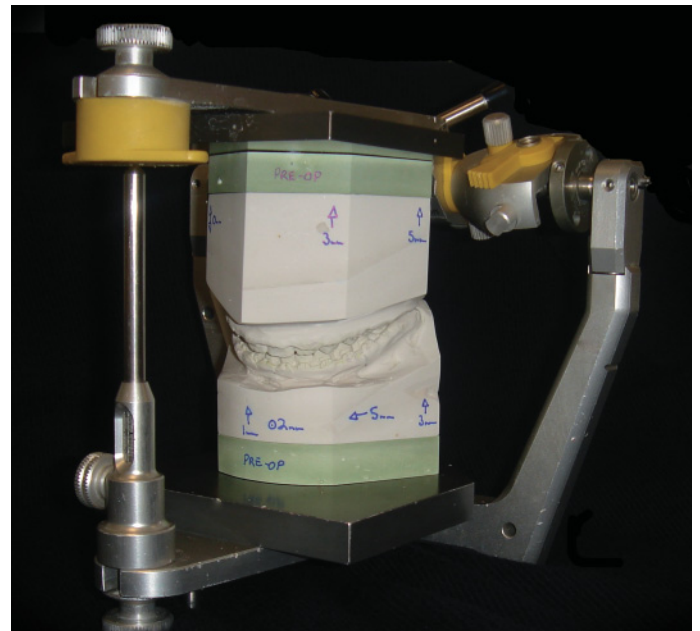


Figure 6.5 Presurgical dental study casts mounted on an adjustable articulator.

condylar hinge axis of the temporomandibular joints), for orthognathic patients requiring *maxillary* surgery (Figure 6.5). Digital study models eliminate the need for storage and permit computerized analysis. Study models have a number of important uses:

- Treatment planning (space analysis in orthodontic treatment).
- Monitoring growth: particularly transverse jaw growth.

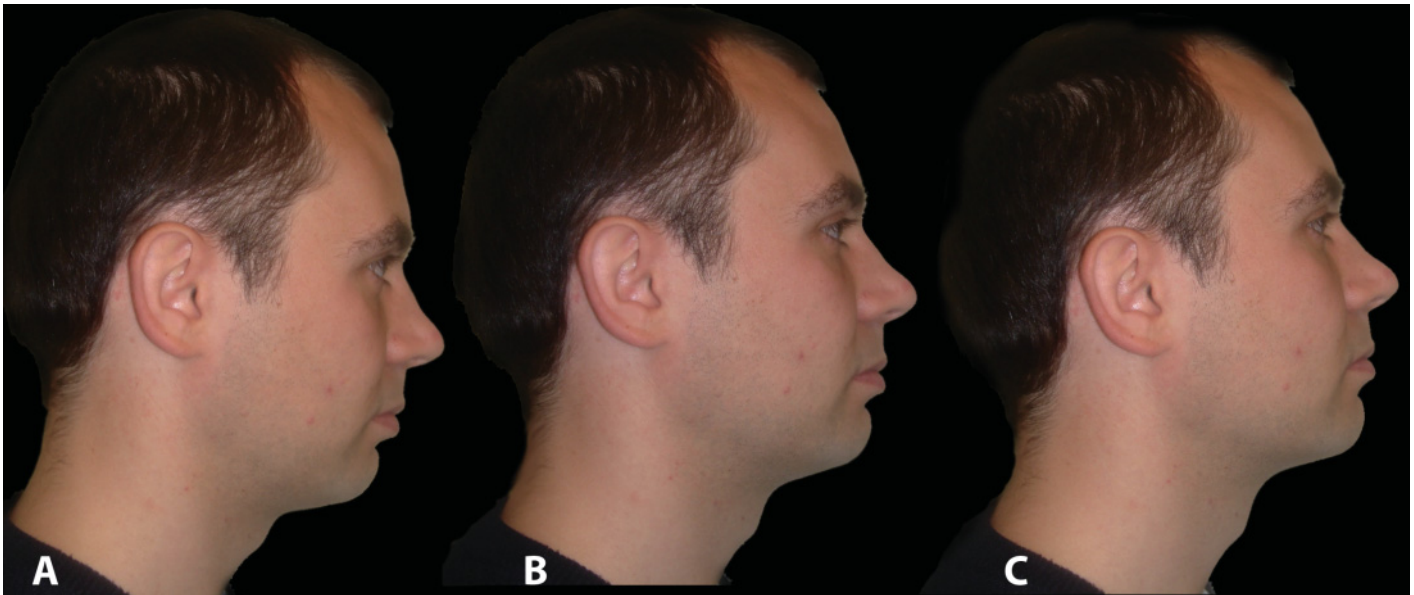


Figure 6.6 (A) Head tilted down; (B) natural head position; and (C) head tilted up.

- Monitoring treatment progress: particularly transverse dental arch changes.
- Diagnostic (Kesling) set-ups: This is a diagnostic procedure, initially described by the orthodontist Harold D Kesling, in which the teeth are cut from a duplicate set of study models and realigned in the desired position using wax to evaluate the predicted results of alternative treatment plans. It effectively provides a three-dimensional road map for treatment.
- Patient communication.
- Teaching, research and audit.
- Medicolegal record.

Serial height measurement

Serial height measurements may be plotted onto a **growth chart** in order to indicate the timing of the **adolescent growth spurt** and to provide an indication of **growth cessation** in preparation for orthognathic surgery, as growth in standing height is well correlated with jaw growth (see Chapter 10, Figure 10.41).

Three-dimensional hard and soft tissue imaging

Computed tomography (CT) is a technique that may be used to generate detailed three-dimensional (3D) images of both the hard and soft tissues of the craniofacial complex. Information from CT scans may be used to provide two-dimensional localized views of the facial skeleton, or 3D computer images that can provide excellent dentoskeletal detail required for the diagnosis of complex dentofacial and craniofacial asymmetry.

3D facial soft tissue scans may also be used to evaluate facial soft tissue morphology and to monitor growth or treatment progress by superimposition of serial scans. The main advantage is no radiation exposure and the possibility of combining 3D CT views of the dentoskeletal structures with a 3D soft tissue facial surface scan. Such technology is currently expensive and the systems require further development.

Natural head position

The comprehensive and accurate clinical evaluation of a patient requires that their head is oriented in what is termed **natural head position (NHP)**. The examination of a patient not in NHP may lead to incorrect diagnosis, particularly of chin position and submental anatomy, and result in incorrect treatment planning of required dentoskeletal and soft tissue changes (Figure 6.6). In addition, the clinical records must be taken with the patient in NHP. This is particularly important for the clinical facial photographs, cephalometric radiographs and, where possible, 3D scans. However, despite its importance, the concept of NHP is often misunderstood or altogether ignored. The reasons for this are partly historical.

The Frankfort Craniometric Agreement and the Frankfort Plane

Anthropologists in the mid to late nineteenth century in Germany had been endeavouring for some time to reach a general agreement among themselves as to a method of measuring skulls that could be generally adopted. The purpose was to obtain standardization of the techniques used by physical anthropologists, particularly in order to undertake comparative studies of the crania from various racial populations. The

outcome of deliberations at two craniometric conferences, held at Munich in 1877 and subsequently Berlin in 1880 was drawn up by Professors Kollman, Ranke and Virchow and submitted for consideration to the 13th General Congress of the German Anthropological Society held in the city of Frankfurt in 1882. Their scheme was adopted and designated the **Frankfort Agreement** (1882), and published in Germany in 1884.¹

To compare various crania in a standardized way, it was necessary to place the skulls in a defined position. Therefore, the

choice of a horizontal reference plane for the orientation of the skulls, the so-called 'German horizontal plane', was agreed upon, which passed through the 'lowest point of the under edge of the orbits and the upper edge of the ear-aperture.'¹ This was the birth of the use of the **Frankfort Horizontal plane** (Figure 6.7).

The unreliability of anatomical reference planes

The Frankfort Horizontal plane was an acceptable compromise for anthropologists studying human crania. However, the use of this plane or any other anatomical reference planes (whether extracranial or intracranial, such as the sella-nasion [S-N] plane), to orientate the head of a patient for clinical evaluation, is subject to considerable error. Human anatomy, and thereby all anatomical landmarks, are subject to **individual biological variation**.

The Frankfort Horizontal plane was chosen by anthropologists as the best anatomical indicator of a physiological position for craniometric studies on skulls. However, living subjects orient their heads in NHP, a physiological position, which feels most natural to them. In many patients the Frankfort Horizontal plane is horizontal when they are in NHP. However, in some patients, particularly individuals with facial deformities, who fall outside the population norms, the orientation of the Frankfort Horizontal plane may vary quite considerably from the true horizontal when they are in NHP. William Downs, one of the pioneers of orthodontics, advised caution in the use of the Frankfort Horizontal plane in a seminal article describing the significant individual variation in the inclination of the Frankfort Horizontal plane (Figure 6.8).² The orthodontist Arne Björk had similarly demonstrated the unreliability of another intracranial reference plane, the S-N plane.³ Two adult Bantu men with almost identical facial profiles in NHP demonstrated considerable difference in the inclination of the S-N plane, illustrating

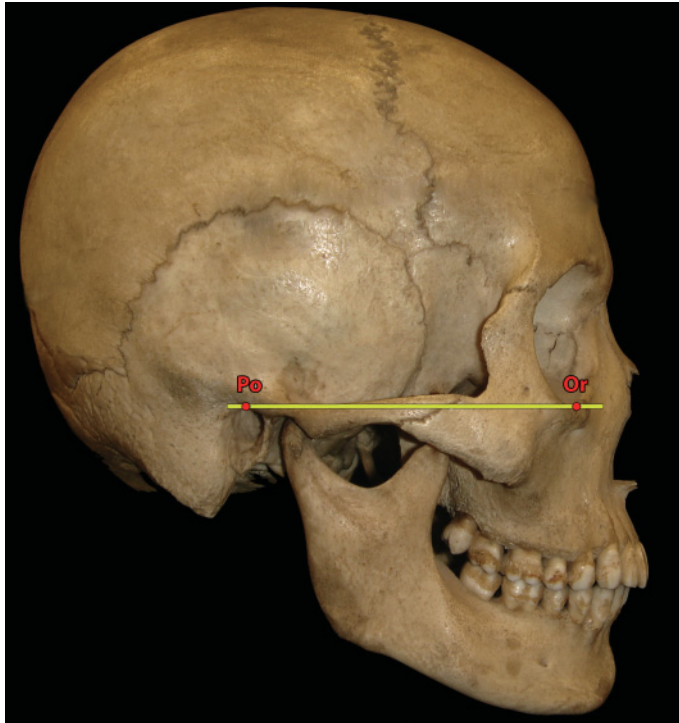


Figure 6.7 The Frankfort Horizontal (FH) plane on a dried skull, extending from the superior border of the external acoustic meatus (porion, Po) to the superior border of the inferior orbital rim (orbitale, Or).



Figure 6.8 Downs described the significant individual variation in the inclination of the Frankfort Horizontal plane (Modified from Downs² with kind permission of the E H Angle Education & Research Fdn., Inc.).

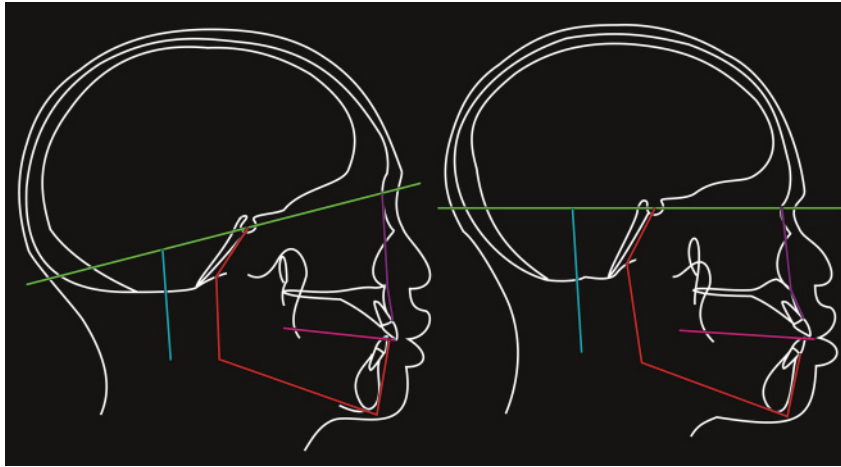


Figure 6.9 Two adult Bantu men with almost identical facial profiles in natural head position demonstrated considerable difference in the inclination of the S-N plane, illustrating the considerable individual variation in the inclination of the anterior cranial base. (Modified from Björk.³ Reproduced with kind permission of The EH Angle Education & Research Fdn., Inc.).

the considerable individual variation in the inclination of the anterior cranial base (Figure 6.9). Moorrees and Kean similarly demonstrated that two women with very similar facial profile contours exhibited marked differences in the inclination of the anterior cranial base (S-N plane) and the Frankfort Horizontal plane (Figure 6.10).⁴

Natural head position: the key to diagnosis

Natural head position may be defined as a standardized and reproducible orientation of the head in space when the subject is focusing on a distant point at eye level. In NHP, the visual axis is horizontal. In order to assess facial proportions accurately patients must be examined in NHP.⁴ This allows an extracranial vertical, and a horizontal perpendicular to that vertical, to be used as reference lines for facial aesthetic analysis. This is important as the inclination or sagittal cant of all anatomical reference lines, such as the Frankfort Horizontal plane, is subject to individual variation.²⁻⁴ The procedure to obtain a clinical facial photograph or cephalometric radiograph in NHP is with the subject standing upright and looking straight ahead into the image of their own eyes in a small mirror located at a distance, at the level of their eyes. NHP has been demonstrated to be reproducible to within 1–2° over a five-year period.⁵

Note

The logical progression to the use of *anatomical* reference planes is to take the cephalometric radiograph with the patient in *physiological* NHP and to derive a **true horizontal plane (TrH)** and a **true vertical plane (TrV)** to which all the craniofacial structures may be related.



Figure 6.10 This superimposition of two women with very similar facial profile contours in natural head position demonstrates the marked differences in the inclination of the anterior cranial base (S-N plane) and the Frankfort Horizontal plane. (Modified from Moorrees and Kean⁴ with kind permission of John Wiley & Sons, 2010.)

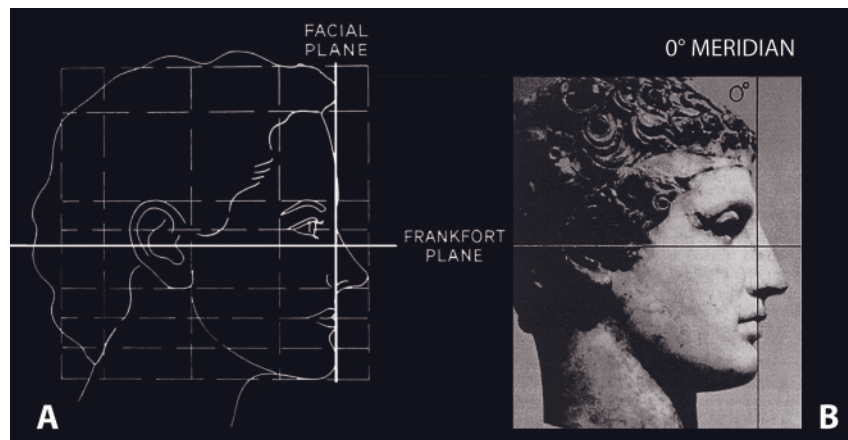


Figure 6.11 The **0° meridian (zero-degree meridian)** was described and named by the Mexican plastic surgeon **Mario Gonzalez-Ulloa** as a vertical line dropped from soft tissue nasion (N'), perpendicular to the Frankfort Horizontal plane.^{6,7} Gonzalez-Ulloa described the concept initially in 1962,⁶ though he used the term (A) 'facial plane', subsequently introducing the term (B) 'true Meridian 0° of the face' in 1968.⁷ (Modified from Gonzalez-Ulloa^{6,7} with kind permission of Wolters Kluwer Health, 2010.)

Choice of horizontal and vertical reference planes

The **0° meridian (zero-degree meridian)** was described and named by the Mexican plastic surgeon **Mario Gonzalez-Ulloa** as a vertical line dropped from soft tissue nasion (N'), perpendicular to the Frankfort Horizontal plane.^{6,7} Gonzalez-Ulloa described the concept initially in 1962,⁶ though he used the term 'facial plane', subsequently introducing the term 'true Meridian 0° of the face' in 1968 (Figure 6.11).⁷ Both the vertical 0°-meridian line and the horizontal line later termed the Frankfort Horizontal plane are evident in the facial diagrams depicted by Leonardo da Vinci (c. 1490) (Figure 6.12).⁸

The concept of using the 0°-meridian is based on the theoretical idea that if the upper facial morphology is normal, in particular the sagittal position of a **reference landmark** such as soft tissue nasion, then the sagittal position of middle and lower facial structures may be determined in relation to a vertical line dropped from soft tissue nasion, perpendicular to the Frankfort Horizontal plane. This overall concept has a number of merits including its ease of use. It has also been demonstrated to be in accord with the 'ideal' classical, Renaissance and neoclassical facial profiles depicted in art and sculpture (Figure 6.13). Nevertheless, two factors must be borne in mind:

- Firstly, the Frankfort Horizontal plane, as with all anatomical reference planes, is subject to **individual variability**. It is particularly unlikely to be perfectly horizontal in patients with dentofacial or craniofacial deformities, in whom planning jaw positions is most important. If the orientation of the Frankfort plane is incorrect, the 0° meridian drawn perpendicular to Frankfort plane will also be incorrect.
- Secondly, using soft tissue nasion as the reference landmark produces another limitation, in that the *morphology of the*

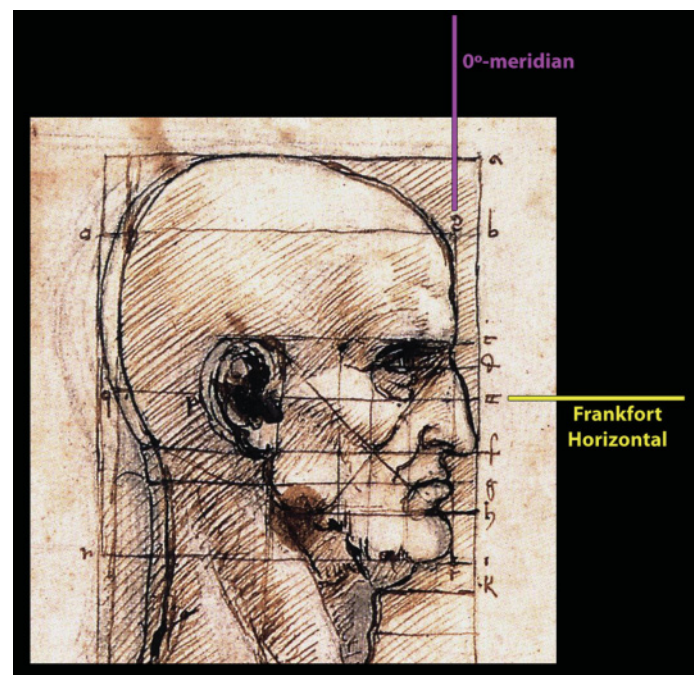


Figure 6.12 The vertical 0° meridian line and the horizontal line later termed the Frankfort Horizontal plane are evident in the facial diagrams depicted by Leonardo da Vinci (mirror image detail, *Male Head in Profile with Proportions*, c. 1490). (Gallerie dell'Accademia, Venice.)

nasal radix and glabellar region is highly variable. Individuals may present with anything from a deep concavity to a relatively flat nasal radix and thereby considerable variation in the sagittal position of soft tissue nasion.

Image not available in the electronic edition

Figure 6.13 The relative orientation of the vertical 0° meridian and the Frankfort Horizontal plane have been demonstrated to be in accord with the 'ideal' classical, Renaissance and neoclassical facial profiles depicted in art and sculpture. (Detail, Roman marble copy of Myron's *Discobolos*. Used with permission © British Museum, London.)

It is therefore necessary to reduce the limitations of using the 0° meridian and Frankfort plane while maintaining the advantages of the overall concept. This may be achieved by evaluating the patient in NHP and constructing a **true vertical plane (TrV)**, drawn parallel to a true vertical plumb line hanging from the ceiling, to replace the 0° meridian, and a **true horizontal plane (TrH)** to replace the Frankfort plane (Figure 6.14). The true vertical plane may be dropped from a **reference landmark** such as soft tissue nasion if the nasal radix region has a normal morphology. The modern desire for a slightly more prominent lower face suggests that the slightly more prominent landmark of soft tissue glabella may replace nasion as the reference landmark. Alternatively, if glabella is too prominent and/or nasion is too deep set, a point between the two may be selected. Another alternative, particularly useful in patients with normal midfacial prominence, is to use a lower reference landmark such as subnasale (the resultant vertical plane termed the **subnasale vertical**, or **SnV**). This is particularly useful for planning mandibular advancement or forward sliding genioplasty in patients with normal midfacial morphology.

Orientation of the patient in natural head position

A number of methods may be employed to position the patient and orientate their head in NHP prior to taking clinical photographs or lateral cephalometric radiographs.

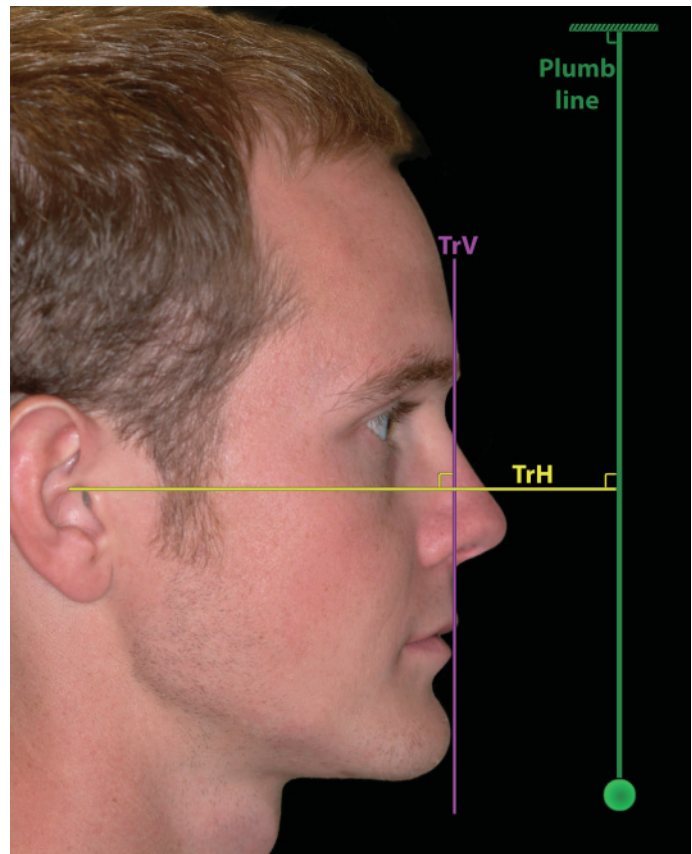


Figure 6.14 A patient in natural head position, demonstrating the true facial vertical (TrV) and true horizontal (TrH) lines used to evaluate facial aesthetics. The true vertical may be taken as a line parallel to a plumb line hanging from the ceiling. The true horizontal will be at right angles to this. In some patients the Frankfort plane may be parallel to the true horizontal; however the inclination of the Frankfort plane is subject to individual variability.

The self-balance position

The self-balance position is defined by the patient's own feeling of a natural head balance.

The mirror position

The subject is instructed to assume a convenient head position while looking straight into the image of his or her eyes in a small mirror positioned at a distance at their eye level.⁹ It is important that the mirror is small when recording NHP, in order to encourage the subject to look straight ahead into the image of their eyes.

The aesthetic position (or 'photographic position' of the head)

The aesthetic position was described by the orthodontist Neville Bass.^{10,11} The standing subject assumes a position that feels natural to them, with subsequent minor adjustment made by the clinician until the head position looks correct to the clinician. This is effectively a *corrected* natural head position. This method is the least time consuming.

The reason that the clinician may need to make minor manual adjustments to the patient's head position is that patients will often have developed a compensatory head posture to minimize the aesthetic impact of their facial appearance, e.g. Class II patients may tilt their heads up to increase their chin prominence, Class III patients may tilt their heads down to reduce chin prominence, and patients with facial asymmetry may tilt their heads around the sagittal axis to reduce the visible asymmetry.

Natural head posture – a note on terminology

The terms 'natural head position' and 'natural head posture' are often, erroneously, used interchangeably in the literature. However, these are distinct terms and not interchangeable. NHP, as already described, is a standardized and reproducible orientation of the head in space when the subject is focusing on a distant point at eye level; a vitally important concept for any clinician involved in facial aesthetic evaluation.

However, natural head posture is a term that was introduced by researchers in their efforts to determine a postural position of the head in order to study the relationship between craniocervical morphology, dentofacial morphology and dentofacial function, particularly respiration. Despite the fact that head posture changes continuously throughout functional activities, Solow and Tallgren selected the so-called **orthoposition** in order to assess patients, defined as the 'intention position from standing to walking', i.e. the momentary position when a subject is taking a first step forwards, which is thought to be reproducible.¹² When taking the lateral cephalometric radiograph of an individual for such research purposes, they suggested the use of a long mirror positioned in front of the subject, to accommodate the different inclinations of their heads.

Therefore, the term natural head posture should not be used other than when researching or describing the postural position of the head in relation to dentofacial morphology or functional activities.

Clinical photography

High-quality, standardized photographic views are a fundamental part of clinical practice in facial aesthetic and reconstructive surgery. Clinical photographs are required for:

- Clinical diagnosis.
- Treatment planning: Clinical photographs may be used with image processing software, often superimposed one-to-one with cephalometric radiographs, to depict the likely results of different surgical procedures, e.g. single jaw or bimaxillary surgery.
- Communication with patients.
- Research.
- Teaching/training and education.
- Medicolegal issues.

Equipment for digital photography and data storage

A digital SLR (single lens reflex) camera, though more expensive than analogue cameras, produces higher-quality images and permits the use of different lenses. A ring flash will provide optimal lighting for intraoral views. Images may be transferred from the camera to a personal computer (PC) by using a card reader; it is also possible to connect the camera directly to the PC via USB connection, but this is often not recommended by camera manufacturers. High-quality lenses are important, permitting a good depth of field.

Digital storage of images is economical in the long run as no films or processing is required. Clinical images should be organized and stored under *patient name* and under specific clinical keywords, e.g. 'rhinoplasty' or 'Class III orthognathic'.

Patient consent forms

The use of *recognizable* patient photographs for scientific lectures, research purposes or medical publication requires the patient's written consent.¹³ The consent form should be easily understood, not exceed one page and make clear that the patient's permission for the use of their clinical photographs is voluntary and withholding consent will in no way affect the proposed treatment or quality of care.

Background and lighting

There are individual preferences for background colour for clinical facial photography. A white background tends to produce excessive shadows, which are particularly negative for facial profile views. Conversely, a black background may produce very little contrast for individuals with dark skin. A light blue (sky blue) or light green background tends to produce a good contrast with most skin tones.¹⁴ A painted wall with a matt finish provides an acceptable background.

A studio-type set-up is the ideal method for obtaining standardized facial photographs. The installation of a ceiling mounted, multi-flashlight system with at least two soft boxes (positioned at an angle of 45°, with a constant distance of 1–1.5 m at either side in front of the patient) or umbrella flashes offers the possibility of constant lighting conditions, even illumination of the subject and avoidance of shadows. A slave-triggered light and slave flash unit may be mounted on the ceiling behind the patient, aimed at the background; this is triggered by the camera flash unit and helps prevent background shadows.

Meneghini advises a single ceiling mounted flash unit, which has the advantage of ease of use and occupies less space.¹⁵ A rectangular soft box fits onto the flash unit in order to soften and diffuse the light. In order to eliminate submental and subnasal shadows the patient holds a small rectangular reflecting panel horizontally against the chest in the collar bone region.

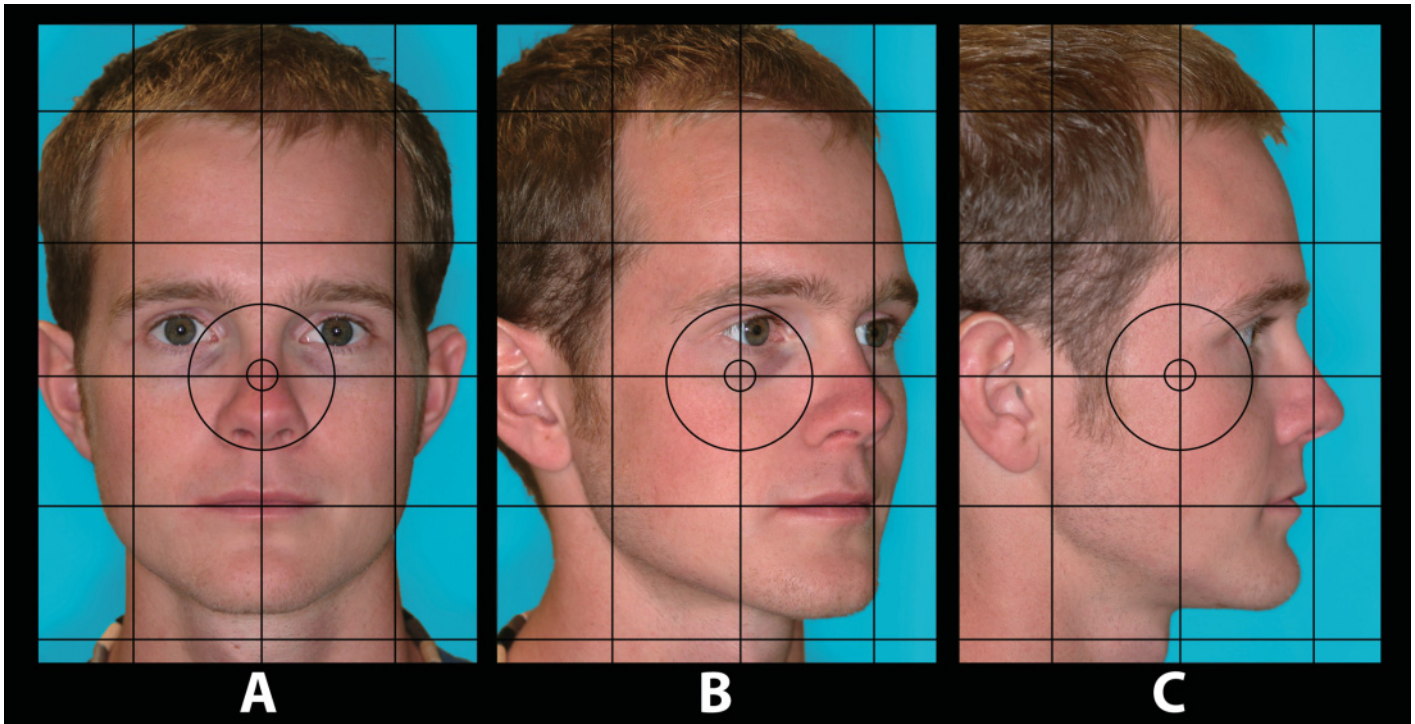


Figure 6.15 A grid pattern focusing screen is useful for orientation, consisting of a series of horizontal and vertical lines together with a circular central focus point. Examples shown are (A) full face frontal view, (B) oblique lateral ($\frac{3}{4}$) view, (C) right profile view, all in repose, with subject in natural head position.

Facial views

It is important for facial photographs to be standardized and reproducible; this is particularly important when comparing the presurgical images with post-surgical results.¹⁶ A constant distance from the subject to the camera may be achieved using marks on the floor showing patient and clinician positions.

Patients should stand in NHP, with the teeth lightly held together and the facial soft tissues in repose. It is important to *take time getting this position correct* otherwise the photographs will achieve no purpose. The camera height should be at an appropriate vertical level, which may be difficult if extreme height differences between patient and clinician exist, in which case the patient may sit on an adjustable chair. Jewellery should be removed and long hair tied back, exposing the ears and the neck.

A grid pattern focusing screen is useful for orientation; when present this is viewed through the camera's view finder. The grid consists of a series of horizontal and vertical lines together with a circular central focus point (Figure 6.15).

The following facial views are required:

- Full face frontal view: in repose and smiling.
- Oblique lateral ($\frac{3}{4}$) view: in repose and smiling (right and left if asymmetry evident).
- Profile view: in repose and smiling (right and left if asymmetry evident).

Additional facial views include:

- Frontal view with lip/cheek retractor: if occlusal plane canting is observed.
- Frontal view with tongue spatula or Fox's guide plane: if occlusal plane canting is observed.
- Submental oblique view: nasal base evaluation.
- Submental vertex (basal) view: mandibular asymmetry.
- Superior view: useful for evaluation of nasal bridge symmetry, horizontal projection of the forehead, orbits, zygomas and paranasal areas.
- Posterior view: ear deformities, particularly excessive lateral projection.

Note

Additional **close-up views** may be taken of any region of interest, such as the eyes, the smile or the nose.

Intraoral views

Clear lip/cheek retractors are required for intraoral photography. The assistant may stand behind the patient and place the retractors. No facial skin or retractor should be visible on an 'ideal' intraoral photograph. Front-silvered glass mirrors are required for the occlusal photographs, which may be warmed under warm water to prevent fogging. Saliva should be aspirated before taking the photographs. The following intraoral views are required (Figure 6.16):



Figure 6.16 Intraoral views. Left panel: right buccal view, overjet view; Middle panel: upper occlusal view, frontal view, lower occlusal view; right panel: left buccal view.

- Frontal view: The camera should be approximately parallel to the occlusal plane, focusing on the maxillary canine crowns.
- Buccal views (right and left).
- Maxillary occlusal view: The image may be mirrored using computer software.
- Mandibular occlusal view: The patient should be instructed to place the tip of the tongue posteriorly (above the mirror). The image may be mirrored using computer software.
- Overjet view (with and without ruler): The left and right buccal views tend to underestimate the size of the incisor overjet; an overjet view taken directly tangent to the labial surface of the incisor teeth provides a more accurate image.

Higher magnification images of individual teeth or areas of enamel hypoplasia or discolouration are taken if required.

Note

Time spent in honing skills in clinical photography is never wasted. Many clinicians will admit that there is a remarkable correlation between a lecturer's surgical competence and the quality of the clinical photographs shown.

Craniofacial anthropometry

'Measurements, to be strictly comparable, must be taken in a strictly defined way and from or between the same anatomical points.'

Aleš Hrdlička (1869–1943), *Anthropometry* (1920)¹⁷

Anthropometry is the scientific study of the measurements and proportions of the human body (Greek *anthrōpos*: 'human being'; *metron*: 'a measure' or 'measurement'). **Craniofacial anthropometry** lies at the heart of evaluating and thereby understanding the normal and abnormal form of the human head and face, which is a prerequisite for clinical diagnosis. Aleš Hrdlička, the Czech physician, physical anthropologist and modern pioneer of anthropometry, stressed that the basis of accurate measurement was the accurate recognition of certain anatomical facial points (or 'landmarks'); this fact was emphasized by Leslie G Farkas, the father of modern craniofacial anthropometry.

Anthropometric craniofacial surface landmarks

The human face has a large number of **reference points**, or topographic surface **landmarks**. A facial landmark may be defined as a readily recognizable point that is visible to the human eye,

but is not divisible into parts, e.g. pronasale or subnasale. Some facial soft tissue landmarks are related to underlying skeletal landmarks, e.g. soft tissue nasion (N') and skeletal nasion (N). Abbreviations of the anthropometric landmarks are marked with lowercase letters in anthropometry, but the first letter is capitalized in clinical practice, e.g. the anthropometrists gonion

is denoted 'go', which in clinical practice is denoted 'Go'. Soft tissue landmarks with equivalent skeletal landmarks are marked with a prime after the abbreviated symbol, e.g. soft tissue nasion is N'. *Knowledge of the precise location of the facial surface landmarks is required in order to obtain reliable linear and angular measurements* (Table 6.1) (Figure 6.17).

Table 6.1 Craniofacial soft tissue surface landmarks (Figure 6.17)

Landmark (abbreviation)	Definition
Vertex (V')	The highest point on the head with the patient in natural head position
Trichion (Tr)	The midline point at the junction of the hairline and forehead (from Greek <i>trikhos</i> : hair); the alternative term is <i>crinion</i> (from Latin <i>crinis</i> : hair)
	Note In patients with a receding hairline , trichion may be located by instructing the patient to raise their eyebrows. The superior aspect of the contraction of the frontalis muscle indicates the position of trichion (Figure 6.18)
Eurion (Eu')	The most prominent lateral soft tissue point overlying each side of the skull in the region of the parietal and temporal bones; it is the most lateral point on the head
Glabella (G')	The most prominent midline point of the forehead between the brow ridges; located at the same vertical level as skeletal glabella on the frontal bone
Opisthocranium (Op')	The most prominent posterior point of the occiput, most distant from glabella
Frontotemporale (Ft')	The most medial point on the temporal crest of the frontal bone; the linear distance Ft'–Ft' represents the soft tissue bitemporal (forehead) width
Nasion (N' or Na')	The point in the midline of the nasal radix and nasofrontal region; located at the same vertical level as skeletal nasion
Palpebrale superius (Ps)	The highest point in the midportion of the free margin of the upper eyelid
Exocanthion (Ex)	The point at the lateral canthus where the superior and inferior eyelids meet
Endocanthion (En)	The point at the medial canthus where the superior and inferior eyelids meet
Palpebrale inferius (Pi)	The lowest point in the midportion of the free margin of the lower eyelid
Orbitale (Or')	The lowest palpable point on the inferior orbital rim
Rhinion (Rh')	The soft tissue point overlying the caudal end of the internasal suture, marking the osseocartilaginous nasal junction; bony rhinion is a craniometric point at the caudal end of the internasal suture
Zygion (Zy')	The most lateral soft tissue point overlying each zygomatic arch; it is identical in position to the underlying skeletal zygion of the zygomatic bones. The distance Zy'–Zy' represents the soft tissue bizygomatic facial width
Tragion (Tr)	The notch in the superior margin of each tragus
Pronasale (Prn)	The most prominent point on the nasal tip
Columella breakpoint (C')	The point at the mid-columella, where the columella takes a more horizontal course, extending posteriorly to subnasale
Alare (Al)	The most lateral point on each alar contour
Alar curvature point (Ac)	The most posterior lateral point of the curvature of the base of each nasal ala, indicating the facial insertion of each nasal ala
Subnasale (Sn)	The deepest midline point where the base of the nasal columella meets the upper lip
Supralabiale (Spl)	The midline point of greatest concavity on the facial contour of the upper lip between subnasale and labrale superius; also termed 'soft tissue A-point'
Labrale superius (Ls)	The midline point representing the mucocutaneous vermilion border of the upper lip
Stomion superius (Sts)	The most inferior midline point of the upper lip
Stomion (St)	The most anterior midline point of contact between the upper and lower lip; if the lips are held apart in repose, a superior and inferior stomion point may be distinguished.

Table 6.1 Continued

Landmark (abbreviation)	Definition
Cheilion (Ch)	The point located at each lateral oral commissure, i.e. the angle of the mouth
Stomion inferius (Sti)	The most superior midline point of the lower lip
Labrale inferius (Li)	The midline point representing the mucocutaneous vermilion border of the lower lip
Sublabiale (Sbl)	The midline point of greatest concavity on the facial contour of the lower lip between labrale inferius and soft tissue menton. It is the deepest point of the mentolabial fold; also termed 'soft tissue B-point'
Pogonion (Pog')	The most prominent midline point of the soft tissue chin pad
Gnathion (Gn')	The most anterior inferior midline point on the soft tissue chin contour; it may be determined by inspection, or constructed as the point of intersection of a vertical tangent to soft tissue pogonion and a horizontal tangent to soft tissue menton, extending the bisector through the anterior inferior curvature of the soft tissue chin pad
Menton (Me')	The most inferior midline point of the soft tissue chin; it is the most inferior point in measuring facial height
Gonion (Go')	The most lateral point on the mandibular (gonial) angle; it is close to skeletal gonion. The distance Go'-Go' represents the soft tissue bigonial width
Cervical point (C)	The innermost point between the submental region and the anterior surface of the neck, in the midsagittal plane. It is located at the intersection of a horizontal tangent to the submental plane and a vertical tangent to the anterior neck plane

Some additional landmarks will be described in the relevant regional sections in Section 3.

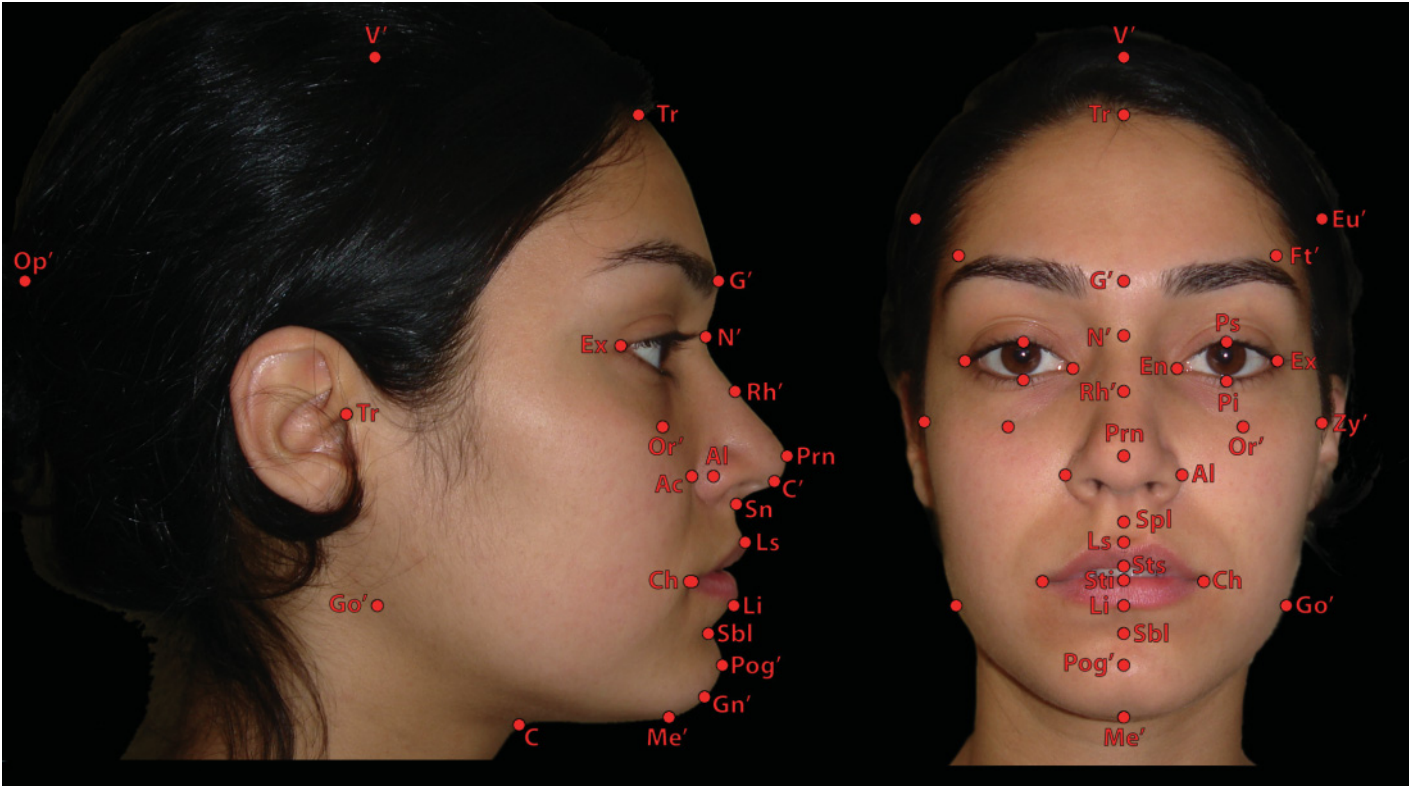


Figure 6.17 Craniofacial soft tissue surface landmarks.

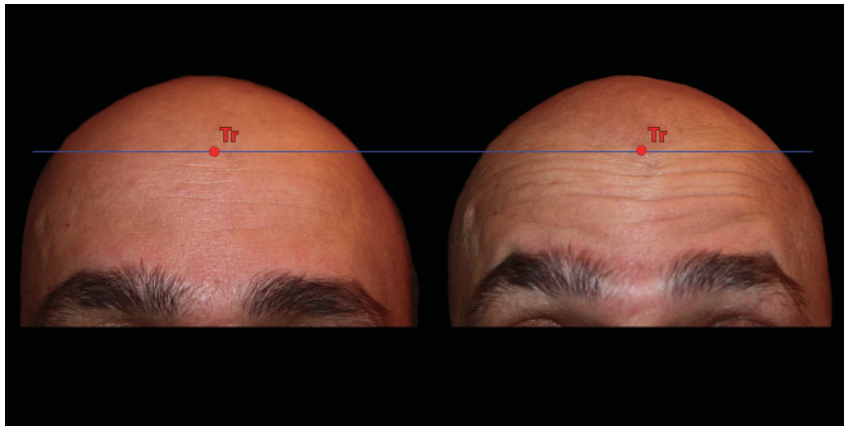


Figure 6.18 In patients with receding hairlines, trichion (Tr) may be located by instructing the patient to raise their eyebrows; the superior aspect of the contraction of the frontalis muscle indicates the position of trichion.

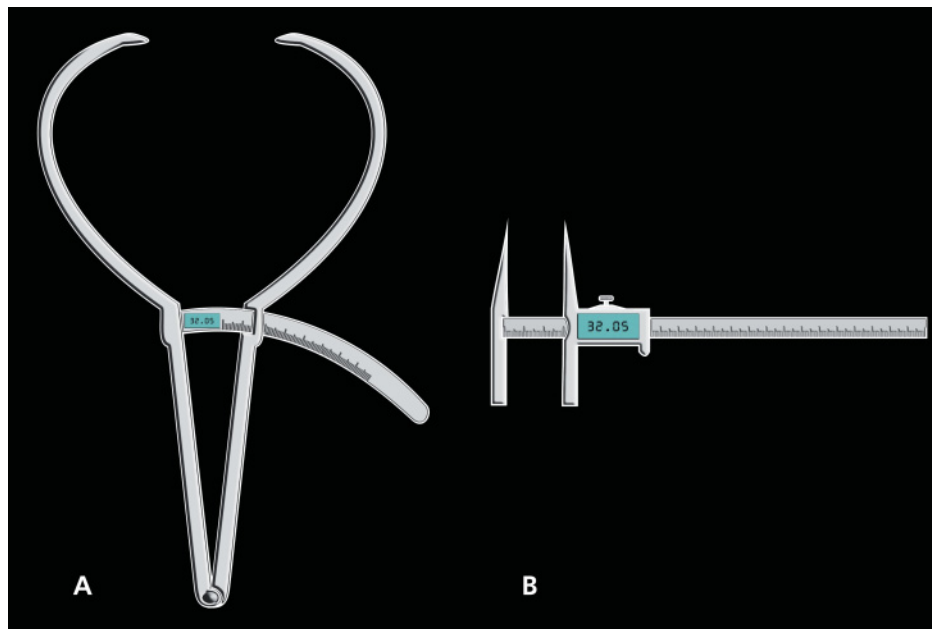


Figure 6.19 (A) Spreading caliper; and (B) sliding caliper.

Note

Accurate location of facial surface landmarks is required for:

- Anthropometric craniofacial analysis.
- Analysing clinical photographs.
- Analysing 3D facial surface scans.

Linear inter-landmark measurements may be made as the shortest straight line distance between two landmarks on clinical photographs. However, on the actual face or on 3D scans, inter-landmark measurement may also be made along the facial surface, i.e. taking into account the surface convexities and concavities.

Note

Accurate anthropometric measurements of the craniofacial complex may be made with a number of **specialized instruments**. The majority of linear measurements may be taken with two standard anthropometric instruments: the **spreading caliper** and the **sliding caliper** (Figure 6.19). Further measurements may be made with a **measuring tape** or specialized **angle finders**, although in clinical practice many of these measurements and angles may be taken from cephalometric radiographs and/or 3D craniofacial images.

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Chapter 7 Cephalometry and Cephalometric Analysis

Introduction

Cephalometry is the scientific measurement of the heads of living individuals (Greek *kephalē*: 'a head'; *metron*: 'a measure' or 'measurement'). **Cephalometric radiography** is a radiographic technique for measurement of the craniofacial complex; it is closely patterned after **craniometry**, which is the scientific measurement of dry skulls used in physical anthropology (Greek *kranion*: skull).

The use of skull radiographs in craniometry was first pointed out by **Pacini** (1922);¹ he demonstrated to anthropologists that accurate cranioskeletal measurements could be made from skull radiographs more easily than from the skull itself. Pacini described the addition of an object of known length to the exposed field and advised the use of a known distance from the X-ray source to the skull. The head-positioning device (cephalometer or cephalostat) and the technique of radiographic cephalometry were introduced in 1931 by the orthodontist **B Holly Broadbent** (1884–1977) in the USA and **Herbert Hofrath** (1899–1952) in Germany, simultaneously but independently of one another.^{2,3} The forerunner to the cephalometer, termed the **Reserve craniostat** (after Case Western Reserve University Medical School in Ohio), was developed by the English surgeon and anatomist **Thomas Wingate Todd** (1885–1938) after his appointment as professor of anatomy at Case Western Reserve University Medical School in the USA. Broadbent worked with Todd and helped to modify the craniostat to permit precise standardization of cranial radiographs of dry skulls.⁴ As a result of his work, Broadbent was assigned to research, under Todd,

the cephalic development of children in a study sponsored by the Brush Foundation, which led to the adaptation of the Reserve craniostat to permit radiographs of the heads of living subjects, hence the development of the roentgenographic cephalometer.⁵

The significance of cephalometric radiography, as opposed to routine skull radiography, was *standardization* of the technique and *reproducibility* of the images. The patient is positioned in the **cephalometer** (or cephalostat) with ear rods placed as a head-holding device (Figure 7.1). The distance from the X-ray source to the patient's midsagittal plane is fixed; the distance from the midsagittal plane to the cassette will be the same for each individual patient. Thus, repeated exposures may be made on successive occasions under standardized conditions. The **lateral cephalometric radiograph** may be conventionally taken with the patient's right side (or left side, depending on the country) located nearest the film. The **posteroanterior (PA) cephalometric radiograph** is taken with the patient facing the film.

Note

It is important to note that the ear rods should not be placed in the ear canals but should just gently contact the facial skin if the transmeatal axis is not perpendicular to the midsagittal plane due to differences in the vertical level of the right and left external acoustic meati.

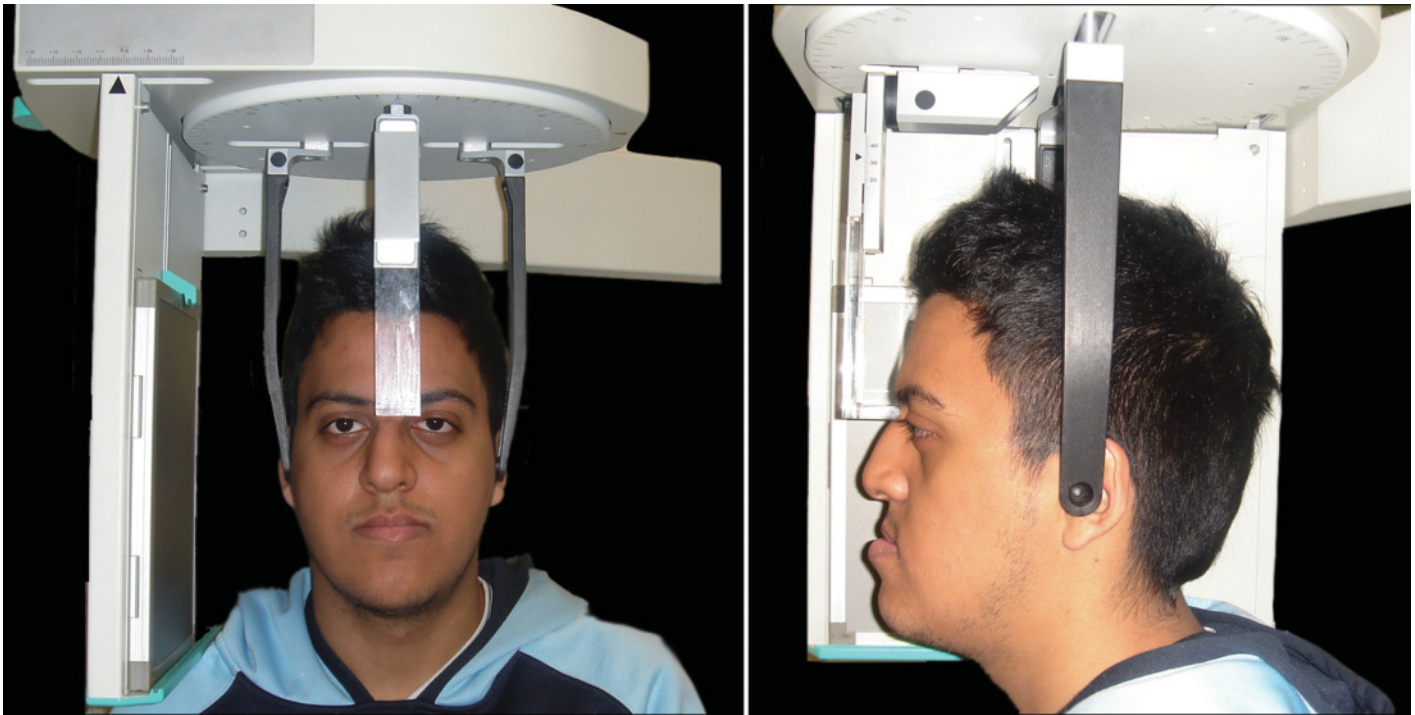


Figure 7.1 A patient positioned in the cephalometer (or cephalostat) with ear rods placed as a head-holding device.

Cephalometric landmarks and planes of reference

Landmarks, lines, planes and volumes

The facial surface and the underlying craniofacial skeleton have a large number of **reference points**, or topographic **landmarks**. An anatomical **landmark** may be defined as a readily recognizable point that is visible to the human eye, but is not divisible into parts, e.g. nasion or menton. Alternatively, visual landmarks that represent the intersections of lines are termed **constructed landmarks** (e.g. articulare). *Knowledge of the precise location of the landmarks on a cephalometric radiograph is required in order to obtain reliable linear and angular measurements* (Tables 7.1–7.3; Figures 7.2–7.4). Points or landmarks joined together continuously in a row form a **line**.¹⁰ A **line** may be defined in that its length may be divided into parts, but it is so slender that it cannot be divided in width; the Greek mathematician Euclid (*fl. c.* 300 BC) wrote: ‘A line is length without breadth’.¹¹ An imaginary straight surface on which a group of lines positioned next to one another would lie is termed a **plane** (Latin *planum*: flat surface). Planes are, by definition, two-dimensional.

In two-dimensional analysis of lateral cephalometric radiographs, some authorities only use the term ‘line’ (as transverse and vertical planes in the frontal view are not visible), whereas others use the term ‘plane’ (as a number of cephalometric ‘lines’ may be thought of as ‘planes’), e.g. the line joining sella and nasion, which approximately indicates the anterior cranial base, may be termed the ‘SN line’ or ‘SN plane’. Both terms are acceptable; it is perhaps more important that in analysing two-

dimensional cephalometric radiographs, clinicians think of cephalometric lines as ‘planes’ in their mind’s eye. Specific planes from which the positions of other craniofacial structures are judged are termed **planes of reference**.

Note

A two-dimensional cephalometric radiograph is a *two-dimensional visual representation of a three-dimensional object*, i.e. the craniofacial complex. Nevertheless, despite this drawback, a thorough understanding of two-dimensional cephalometry and cephalometric analysis has been the prerequisite to understanding the structural relationships of the craniofacial complex. Additionally, the majority of available data from longitudinal growth studies is based on two-dimensional cephalometry. Although some of these data are applicable to the three-dimensional model, such as measurements taken in the midsagittal plane, much of the data will not be directly applicable.

The advantage of three-dimensional cephalometric images viewed on a computer monitor is that the image may be viewed from *multiple perspectives*. The analysis of three-dimensional cephalometric images permits the use of **solid geometric analysis**, as opposed to two-dimensional **plane geometric analysis**. Therefore, in addition to linear and angular measurements, **volumetric measurements** may also be taken (solid geometric analysis). It is important to bear in mind, however, that a thorough understanding of two-dimensional cephalometric analysis is indisputably important for understanding the craniofacial complex and analysing three-dimensional images.

Hard tissue lateral cephalometric (skeletal) landmarks

See Table 7.1 and Figure 7.2.

Table 7.1 Hard tissue lateral cephalometric (skeletal) landmarks

Landmark (abbreviation)	Definition
<i>Anterior facial landmarks (from superior to inferior)</i>	
Glabella (G)	The most prominent point of the anterior contour of the frontal bone in the midsagittal plane, in the supraorbital and frontal sinus region
Nasion (N or Na)	The intersection of the internasal and frontonasal sutures, in the midsagittal plane
Frontonasomaxillary point (FNM or M-point)	The point at the junction of the nasofrontal and nasomaxillary sutures, designated as M-point by the craniofacial surgeon Jean Delaire; it is used to construct the 'superior cranial base line' by joining M-point with the apex of the posterior clinoid process (Pcp) in the Delaire craniofacial analysis ^{6,7}
Orbitale (Or)	The lowest point on the inferior orbital rim (bilateral)
Anterior nasal spine (ANS)	The tip of the bony anterior nasal spine; this point corresponds to the anthropological point 'acanthion'
A-point (Point A; subspinale)	The point at the deepest midline concavity on the maxillary alveolus between anterior nasal spine and prosthion
Prosthion (Pr; Supradentale, Sd)	The most inferior anterior point on the maxillary alveolar process, between the maxillary central incisors, in the midsagittal plane
Infradentale (Id)	The most superior anterior point on the mandibular alveolar process, between the mandibular central incisors, in the midsagittal plane
B-point (Point B; supramentale)	The point at the deepest midline concavity on the mandibular <i>alveolus</i> between infradentale and pogonion
D-point (point D)	This is the centre of the body of the mandibular symphysis (bony chin) in the midsagittal plane and is estimated visually. The angle SND was described by the orthodontist Cecil Steiner to provide an assessment of the sagittal position of the mandibular skeletal base in relation to the anterior cranial base ^{8,9}
Pogonion (Pog)	The most anterior point on the contour of the mandibular symphysis, in the midsagittal plane
Gnathion (Gn)	The most anterior inferior point on the mandibular symphysis (bony chin), in the midsagittal plane. It may be determined by inspection, or constructed as the point of intersection of a vertical tangent to pogonion and a horizontal tangent to menton, extending the bisector through the anterior inferior curvature of the mandibular symphysis
Menton (Me)	The most inferior point of the mandibular symphysis, in the midsagittal plane
<i>Posterior facial landmarks (approximately from superior to inferior)</i>	
Sella entrance point (Se)	The midpoint of the entrance to the sella turcica
Sella (S)	The point representing the geometric centre of the pituitary fossa (sella turcica), in the midsagittal plane
Posterior clinoid process point (Pcp)	The most superior point on the contour of the posterior clinoid process
Porion (Po)	The 'anatomical' porion is the most superior point of the outline of the external auditory meatus (bilateral). The use of ear rods in the cephalostat often makes anatomical porion difficult to locate, in which case the superior margin of the glenoid fossa of the temporomandibular joint that lies at the same level may be substituted for constructing the Frankfort Horizontal plane. The term 'machine' porion refers to the most superior point of the image of the ear rods, which some authorities use as an alternative
Condylion (Co)	The most posterior superior point on the head of the mandibular condyle (bilateral)
Condylar midpoint (Con)	This is the arbitrary centre of the mandibular condyle in lateral view; it is estimated visually (alternative term is capitulare). An imaginary line through point Con of both mandibular condyles forms the condylar hinge axis , around which the mandible may rotate during the initial part of the opening movement

Table 7.1 Continued

Landmark (abbreviation)	Definition
Articulare (Ar)	The point of intersection of the images of the posterior border of the mandibular ramus and the inferior border of the basilar part of the occipital bone (bilateral). It may be used as a substitute for condylion if the latter is not readily discernible; articulare is often the most superior point on the mandibular ramus that can be consistently identified. It was defined by the orthodontist Arne Björk. Any opening or closing movements of the mandible will alter its position
Basion (Ba)	The most inferior point on the anterior margin of the foramen magnum, in the midsagittal plane
Opisthion (Op)	The most inferior point on the posterior margin of the foramen magnum, in the midsagittal plane
Bolton point (Bo)	The highest point on the upward curvature of the outlines of the retrocondylar fossae of the occipital bone, approximating the centre of the foramen magnum; named by the orthodontist B Holly Broadbent in honour of the philanthropist Charles B Bolton ²
Pterygomaxillare superius (Ptms)	The pterygomaxillary fissure is a bilateral teardrop-shaped area of radiolucency, the anterior surface of which represents the posterior surfaces of the maxillary tuberosities. The landmark is the most superior point of the pterygomaxillary fissure (bilateral)
Pterygomaxillare (Ptm)	The most inferior point at the junction of the anterior and posterior borders of the pterygomaxillary fissure (bilateral); this point is in very close proximity to PNS
Posterior nasal spine (PNS)	The most posterior point on the bony hard palate, in the midsagittal plane. It may be located by extending the anterior wall of the pterygomaxillary fissure inferiorly to intersect the hard palate
Gonion (Go)	The most inferior posterior point on the contour of the angle of the mandible (gonial angle). It may be determined by inspection, or constructed as the point of intersection of the posterior ramal plane and mandibular plane, extending the bisector through the curvature of the gonial region of the mandible (bilateral)
Hyoid point (Hy)	The most anterior superior point on the body of the hyoid bone, also termed 'hyoidale'

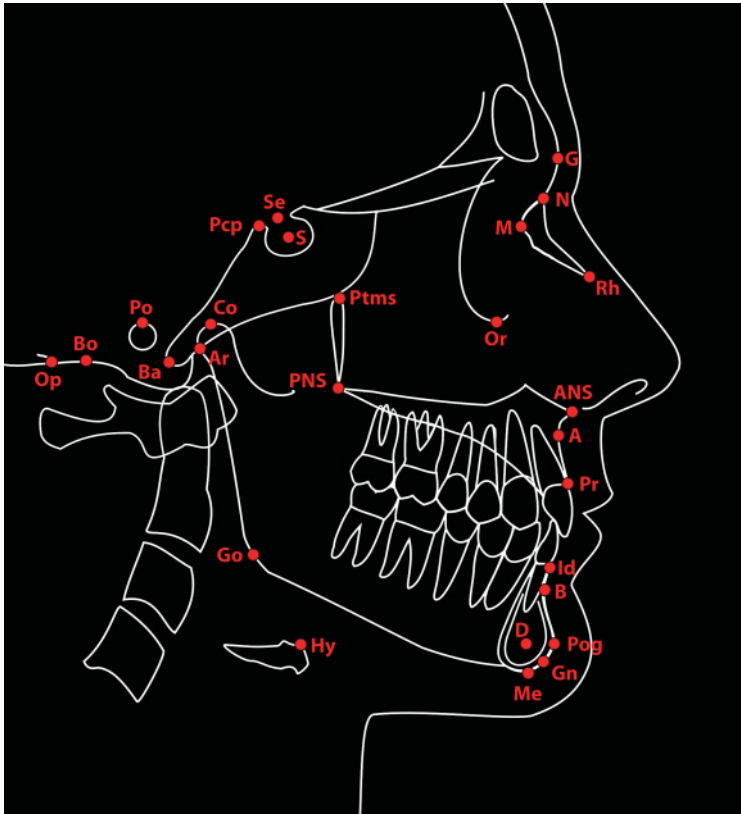


Figure 7.2 Hard tissue lateral cephalometric landmarks (skeletal) (see Table 7.1 for definitions).

Hard tissue lateral cephalometric (dental) landmarks

See Table 7.2 and Figure 7.3.

Table 7.2 Hard tissue lateral cephalometric (dental) landmarks

Landmark (abbreviation)	Definition
Centroid (centre of resistance, Cr)	The midpoint of the root axis of the most prominent maxillary incisor (see note below)
Incision superius apicalis (Isa)	The root apex of the most anterior maxillary central incisor
Incision superius incisalis (Isi)	The tip of the incisal edge of the most labially positioned maxillary central incisor crown
Incision inferius incisalis (Iii)	The tip of the incisal edge of the most labially positioned mandibular central incisor crown
Incision inferius apicalis (Iia)	The root apex of the most anterior mandibular central incisor
Mx6.mbc	The mesiobuccal cusp tip of the maxillary first molar crown
Mn6.mbc	The mesiobuccal cusp tip of the mandibular first molar crown

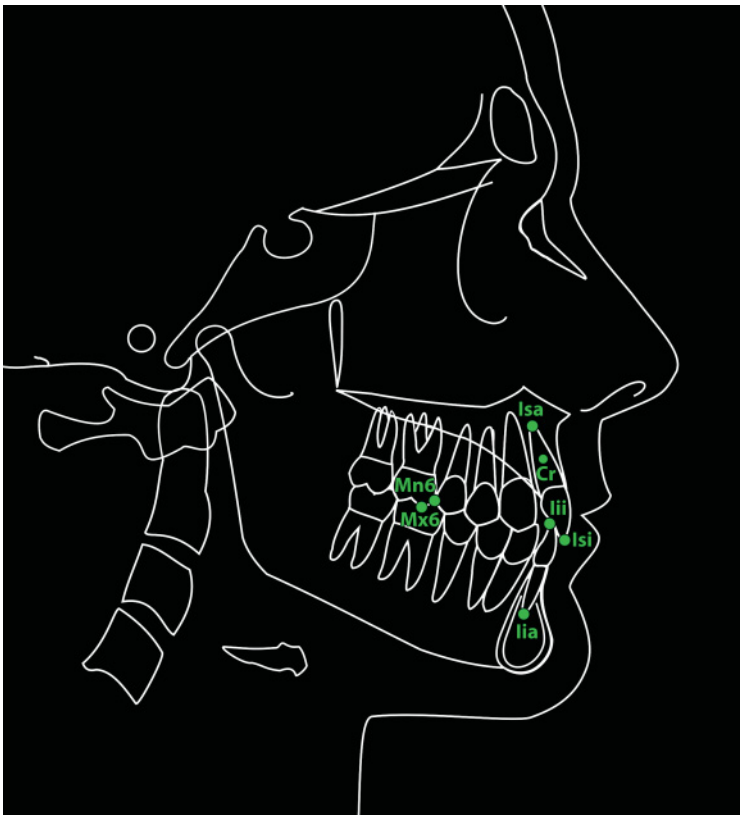


Figure 7.3 Hard tissue lateral cephalometric landmarks (dental) (see Table 7.2 for definitions).

Note

The **centre of resistance** or **centroid** (Cr) may be defined as the point within a tooth on which the application of a single point force may produce bodily movement of the tooth. The precise location of the centre of resistance of teeth is a somewhat contentious issue. Assuming intact periodontal support, the Cr of a single-rooted tooth, such as a maxillary central

incisor, is estimated to be anywhere between one-third and two-thirds along the distance between the root apex and the crest of the alveolar bone. Therefore, the midpoint of the root axis of the embedded portion of a maxillary central incisor root is an acceptable compromise.

Soft tissue lateral cephalometric landmarks

See Table 7.3 and Figure 7.4. It is useful to compare the definitions of these soft tissue cephalometric landmarks with the anthropometric landmarks described in Table 6.1 (Chapter 6).

Table 7.3 Soft tissue lateral cephalometric landmarks

Landmark (abbreviation)	Definition
Glabella (G')	The most prominent point of the soft tissue anterior contour of the forehead in the midsagittal plane, in the supraorbital brow ridge region, in the midsagittal plane
Nasion (N' or Na')	Cephalometric soft tissue nasion is <i>usually</i> the point of deepest concavity of the soft tissue contour of the root of the nose, in the midsagittal plane. Soft tissue nasion (N') and skeletal nasion (N) should be at the same vertical level. In some individuals there is an anterior curvature of the superior portion of the nasal bones; in such patients the deepest point of the nasal radix is termed 'sellion' (or 'subnasion'), which is inferior and usually posterior to soft tissue nasion.
Rhinion (Rh')	The soft tissue point overlying the caudal end of the nasal bones in lateral view, marking the osseocartilaginous nasal junction
Pronasale (Prn)	The most prominent point of the nasal tip, in the midsagittal plane
Subnasale (Sn)	The point where the base of the nasal columella meets the upper lip, in the midsagittal plane
Soft tissue A-point (supralabiale, Spl)	The point of greatest concavity of the facial contour of the upper lip between subnasale and labrale superius, in the midsagittal plane
Labrale superius (Ls)	The point representing the mucocutaneous vermilion border of the upper lip, in the midsagittal plane
Stomion superius (Sts)	The most inferior point of the upper lip, in the midsagittal plane
Stomion (St)	The most anterior point of contact between the upper and lower lip, in the midsagittal plane. If the lips are held apart in repose, a superior and inferior stomion point may be distinguished
Stomion inferius (Sti)	The most superior point of the lower lip, in the midsagittal plane
Labrale inferius (Li)	The point representing the mucocutaneous vermilion border of the lower lip, in the midsagittal plane
Soft tissue B-point (sublabiale, Sbl)	The point of greatest concavity of the facial contour of the lower lip between labrale inferius and soft tissue menton. It is the deepest point of the mentolabial fold
Pogonion (Pog')	The most anterior point on the contour of the soft tissue chin, in the midsagittal plane
Gnathion (Gn')	The most anterior inferior point on the soft tissue chin contour, in the midsagittal plane. It may be determined by inspection, or constructed as the point of intersection of a vertical tangent to soft tissue pogonion and a horizontal tangent to soft tissue menton, extending the bisector through the anterior inferior curvature of the soft tissue chin pad
Menton (Me')	The most inferior point of the soft tissue chin, in the midsagittal plane
Cervical point (C)	The innermost point between the submental region and the anterior surface of the neck, in the midsagittal plane. It is located at the intersection of a horizontal tangent to the submental plane and a vertical tangent to the anterior neck plane

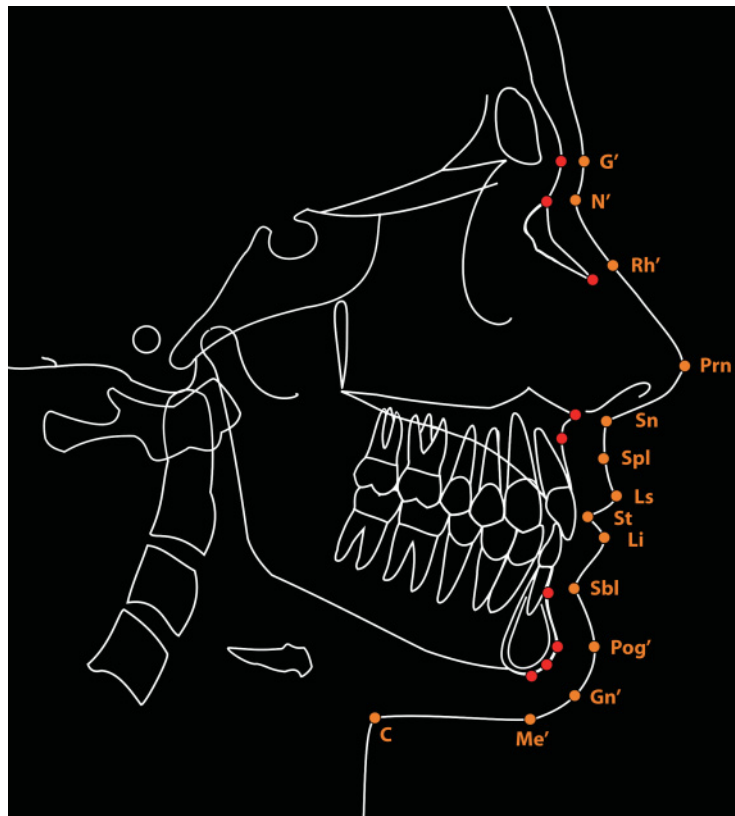


Figure 7.4 Soft tissue lateral cephalometric landmarks (see Table 7.3 for definitions).

Cephalometric planes of reference

Following the location of the reference points (landmarks), it is possible to draw reference lines/planes. **Linear measurements** may be made by connecting two landmarks; **angular measure-**

ments may be made by connecting three landmarks. Numerous lines/planes may be used depending on the cephalometric analysis being employed, and each analysis is based around one or more **reference planes** (Tables 7.4 and 7.5; Figures 7.5 and 7.6).

Note

Each cephalometric analysis used in craniofacial evaluation requires one or more **reference lines/planes**, which are formed by joining some **reference landmarks** or points (other than the true horizontal and true vertical lines). *Variations in the position of reference landmarks and thereby the orientation of reference lines will affect measurements.* Therefore the effectiveness and practicality of each analysis depends on whether the selected reference points are in 'ideal' positions,

and thereby depends significantly on the presenting craniofacial deformity. For example, the sagittal position of the bony chin may be related to a perpendicular line from the Frankfort Horizontal plane through nasion, but this will only be useful if the sagittal position of nasion is correct and the orientation of the Frankfort plane is 'ideal'. The only reference lines not subject to such problems are the **true horizontal** and **true vertical planes**, based on natural head position (NHP).

Hard tissue lateral cephalometric reference planes

See Table 7.4 and Figures 7.5 and 7.6.

Table 7.4 Hard tissue lateral cephalometric reference planes

Landmark (abbreviation)	Definition
<i>Horizontal reference planes</i>	
Sella entrance to nasion (Se-N) plane	A line joining the sella entrance point (Se) to nasion
Delaire horizontal line (superior cranial base line)	A line joining M-point with the apex of the posterior clinoid process (Pcp); described by the craniofacial surgeon Jean Delaire ^{6,7}
Sella-nasion (S-N or SN) plane	A line joining sella and nasion, approximately indicating the anterior cranial base
Optic plane	The 'supraorbital plane' is drawn tangent to the superior contour of the anterior clinoid process and the roof of the orbit; the 'infraorbital plane' is drawn tangent to the lower border of sella turcica and the floor of the orbit; the 'optic plane' bisects the angle formed by the supraorbital and infraorbital planes; described by the orthodontist Viken Sassouni as an alternative to the Frankfort Horizontal plane ¹²
Frankfort Horizontal (FH) plane	A horizontal line connecting the cephalometric landmarks porion and orbitale
Constructed Frankfort Horizontal (FHc) plane	A horizontal line drawn through sella at 7° less than the sella-nasion line; described by the orthodontist Charles Burstone ¹³
Maxillary plane (MxP; palatal plane)	A line joining posterior nasal spine (PNS) and anterior nasal spine (ANS)
Occlusal plane (OP)	A line on the cephalometric radiograph representing an imaginary plane at the level of the dental occlusion. Three distinct planes may be defined: • Maxillary occlusal plane (MxOP): A line joining the maxillary first permanent molar cusp tips to the incisal edges of the maxillary central incisors • Mandibular occlusal plane (MnOP): A line joining the mandibular first permanent molar cusp tips to the incisal edges of the mandibular central incisors • Functional occlusal plane (FOP): A line drawn passing through the occlusion of the premolars (or deciduous molars) and the maxillary and mandibular first permanent molars
Mandibular plane (MnP)	A line/plane connecting gonion and menton, representing the inferior border of the mandible in the sagittal plane; the mandibular plane may also be drawn as a tangent to the inferior border of the mandible.
<i>Vertical reference planes</i>	
Nasion perpendicular (N-perpendicular)	A line drawn perpendicular to the Frankfort Horizontal (or ideally the true horizontal) plane from nasion; described by the orthodontist James McNamara Jr
Facial plane (skeletal)	A line joining nasion to pogonion
Delaire vertical line	The 'craniofacial balance line' described by Delaire is a vertical line dropped from a point slightly posterior to M-point along the M-Pcp horizontal line (the point representing the articulation of the frontal process of the maxilla with the lacrimal bone); in an attractive Caucasian profile this line is said to pass through the nasopalatine foramen and bony menton, thereby determining the sagittal position of the maxillary and mandibular skeletal bases ^{6,7}
A-Pog line	A line connecting maxillary point A to bony pogonion; described by the orthodontist Robert Ricketts, used in the Downs analysis and popularized by Raleigh Williams (1969) ¹⁴
Y-axis	A line joining sella and gnathion
Facial depth line	A line joining nasion and gonion
Posterior ramus plane	This plane is tangent to the posterior border of the mandibular ramus

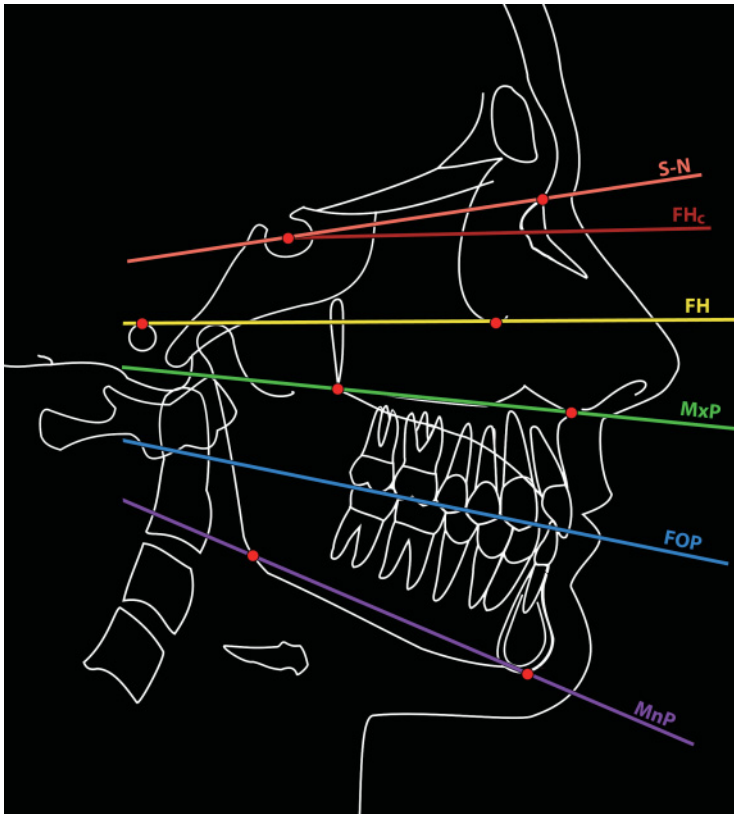


Figure 7.5 Hard tissue lateral cephalometric (horizontal) reference planes (see Table 7.4 for definitions).

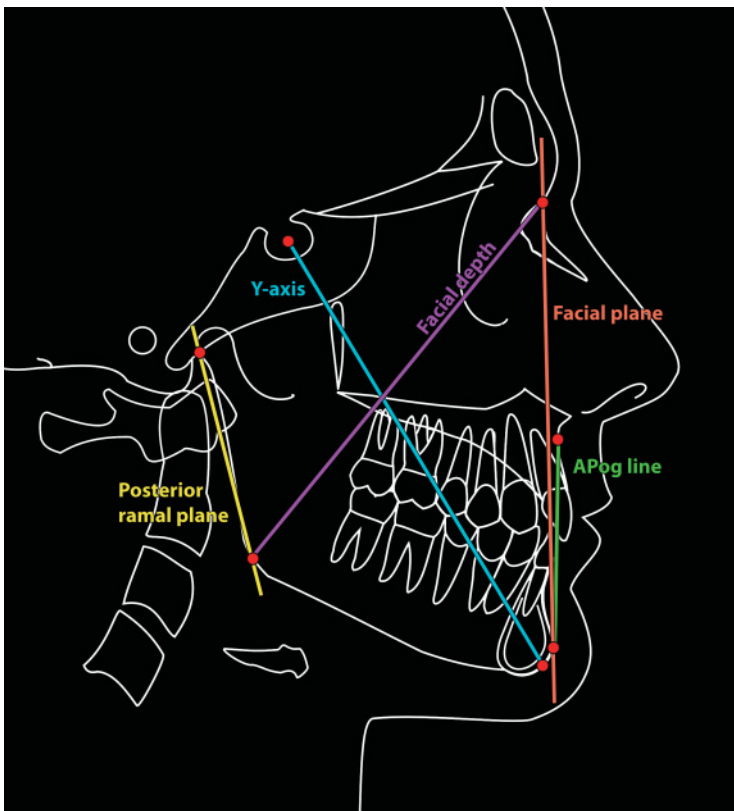


Figure 7.6 Hard tissue lateral cephalometric (vertical) reference planes (see Table 7.4 for definitions).

Soft tissue lateral cephalometric reference planes

See Table 7.5. These lines and planes will be illustrated throughout the chapters in Part II.

Table 7.5 Soft tissue lateral cephalometric reference planes

Landmark (abbreviation)	Definition
E-line ('Esthetic' line/ plane of Ricketts)	Described by the orthodontist Robert Ricketts, ^{15,16} a line tangent to the chin (pogonion) and nasal tip (pronasale); it is used to analyse the prominence of the lips
Facial plane (soft tissue)	A line joining soft tissue nasion to soft tissue pogonion
H-line (Harmony line of Holdaway)	Described by the orthodontist Reed Holdaway, ^{17,18} the H-line (Harmony line) is drawn from soft tissue pogonion (Pog') tangent to the upper lip (Ls)
Rees aesthetic plane	Described by the plastic surgeon Thomas D Rees, ¹⁹ this is a line tangent to the nasal tip (pronasale) and upper lip (labrale superius), which should pass near the <i>bony</i> pogonion in an attractive facial profile
Riedel plane	Described by the orthodontist Richard Riedel, ²⁰ a line tangent to the upper lip, lower lip and soft tissue pogonion; its advantage is that it eliminates the nasal prominence from the analysis
S-line (Steiner line)	Described by the orthodontist Cecil Steiner, ^{8,9} the S-line is drawn from the midpoint of the S-shaped curve between subnasale (Sn) and pronasale (Pn) to soft tissue pogonion (Pog'). It is used to analyse the prominence of the lips
Sn-Pog' line (Burstone)	Described by the orthodontist Charles Burstone, ¹³ the subnasale to soft tissue pogonion line may be used to evaluate lip prominence. The advantage is that it eliminates the nasal prominence from the analysis
Zero degree (0°) meridian (Gonzalez Ulloa)	Described by the plastic surgeon Mario Gonzalez Ulloa, ^{21,22} it is a vertical line dropped from soft tissue nasion, perpendicular to the Frankfort Horizontal plane
Z-line (Merrifield)	Described by the orthodontist Levern Merrifield, ²³ the profile line, or Z-line, is drawn tangent to soft tissue pogonion (Pog') and to the most prominent point of either the lower or upper lip, whichever is most prominent. Ideally, the upper lip should fall on the line and the lower lip should be slightly behind. The angle formed by the intersection of this profile line and the Frankfort Horizontal plane (or ideally the true horizontal plane) is referred to as the Z-angle

Posteroanterior cephalometric radiography

Individuals presenting with **facial asymmetry** require evaluation of the facial skeleton in the frontal view with a posteroanterior (PA) cephalometric radiograph (Table 7.6 and Figure 7.7). This radiograph is ideally taken with the patient in natural head

position (NHP). Identification of the midsagittal plane permits evaluation of **bilateral dentoskeletal symmetry**. This is followed by identification of bilateral landmarks, which are connected as horizontal lines to form transverse planes; the **relative orientation** of these planes aids in the evaluation of **vertical skeletal asymmetry** (Table 7.7 and Figure 7.8).

Hard tissue posteroanterior cephalometric landmarks

See Table 7.6 and Figure 7.7.

Table 7.6 Hard tissue posteroanterior cephalometric landmarks

Landmark (abbreviation)	Definition
<i>Midline landmarks</i>	
Crista galli (Crg)	The most superior point of the crista galli
Anterior nasal spine (ANS)	The centre (tip) of the bony anterior nasal spine
Incision superius frontale (Isf)	The midpoint contact between the maxillary central incisors at the level of the incisal edges
Incision inferius frontale (Iif)	The midpoint contact between the mandibular central incisors at the level of the incisal edges
Menton (Me)	The midpoint on the inferior border of the mandibular symphysis
<i>Bilateral landmarks</i>	
Eurion (Eu)	The most prominent lateral point on the side of the skull in the region of the parietal and temporal bones; it is the most lateral point on the cranium
Latero-orbitale (Lo)	The intersection of the lateral orbital contour with the 'innominate line'; the innominate line represents the tangentially viewed temporal surface of the greater wing of the sphenoid
Medio-orbitale (Mo)	The intersection of the medial orbital contour with the superior contour of the lesser wing of the sphenoid
Zygion (Zy)	The most lateral point on the zygomatic arch
Maxillare (Mx)	The intersection of the lateral contour of the maxillary alveolar process and the inferior contour of the zygomatic process of the maxilla
Mx6.bs	The most prominent lateral point on the buccal surface of the first permanent maxillary molar
Mn6.bs	The most prominent lateral point on the buccal surface of the first permanent mandibular molar
Mastoidale (Ms)	The most inferior point of the mastoid process
Mental foramen (Mf)	The centre of the mental foramen
Gonion (Go)	The most inferior, posterior and lateral point at the angle of the mandible
Antegonion (Ag)	The most superior point in the antegonial notch

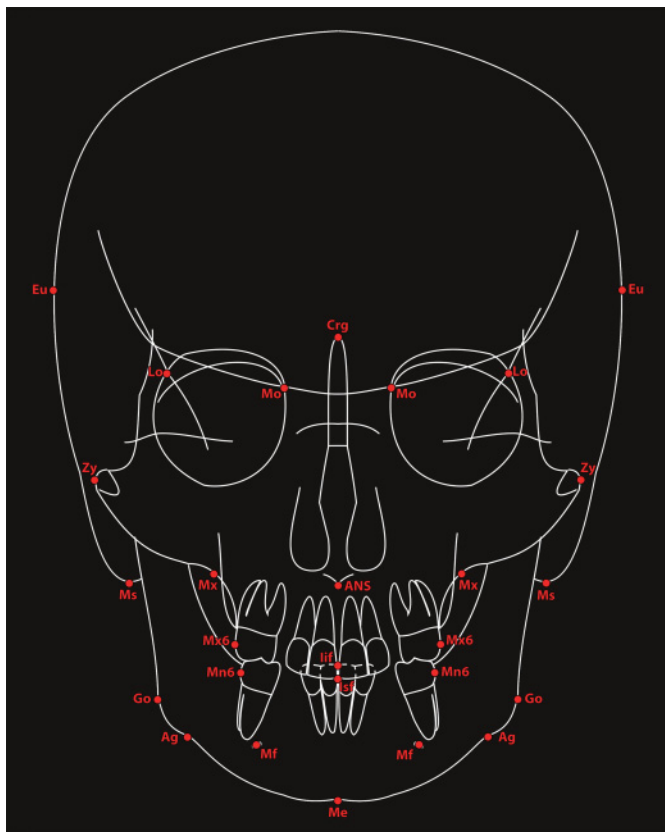


Figure 7.7 Hard tissue posteroanterior (PA) cephalometric landmarks (see Table 7.6 for definitions).

Hard tissue posteroanterior cephalometric reference planes

See Table 7.7 and Figure 7.8.

Table 7.7 Hard tissue posteroanterior cephalometric reference planes (numbers refer to Figure 7.8)

Landmark (abbreviation)	Definition
<i>Vertical reference planes</i>	
Midsagittal plane	A vertical line drawn through crista galli and nasion, parallel to a true vertical line; it should pass through ANS, between the central incisor teeth and through menton
<i>Horizontal reference planes</i>	
1 Superior transorbital plane	A line connecting the most superior point on the contour of the left and right superior orbital outlines
2 Inter latero-orbitale plane	A line connecting the left and right latero-orbitale (Lo) points
3 Inter medio-orbitale plane	A line connecting the left and right medio-orbitale (Mo) points
4 Transpetrous plane	A line connecting the most superior point on the outline of the left and right petrous part of the temporal bone
5 Interzygomatic plane	A line connecting left and right zygion (Zy) points
6 Inferior transorbital plane	A line connecting the most inferior point on the contour of the left and right inferior orbital outlines
7 Intermaxillare plane	A line connecting left and right maxillare (Mx) points
8 Occlusal plane	The transverse occlusal plane may be evaluated by a line connecting the left and right maxillary and mandibular buccal molar cusps; there may be separate maxillary and mandibular planes in the presence of lateral open bites
Canine line	A separate maxillary and mandibular canine line may be drawn connecting the left and right canine cusp tips
9 Incisal line	A separate maxillary and mandibular incisal line may be drawn tangent to the incisal edges
10 Intergonial (bigonial) plane	A line connecting the left and right bony gonion points at the mandibular angles
11 Inter mental foramen plane	A line connecting the centre of the left and right mental foramina; this landmark is easier to identify on three-dimensional reconstructions
12 Inferior chin plane	A line drawn on the inferior border of the chin through menton, with maximum bone contact

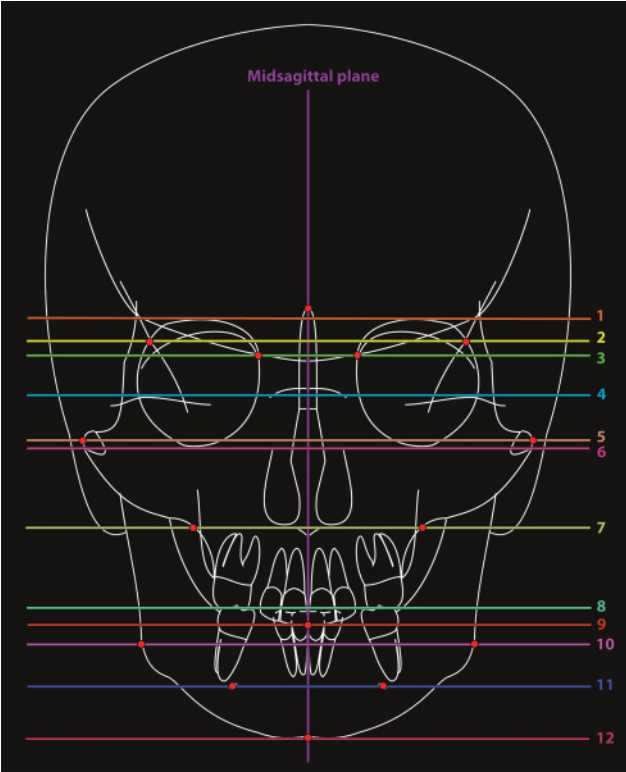


Figure 7.8 Hard tissue posteroanterior (PA) cephalometric reference planes (numbers refer to Table 7.7).

Cephalometric analysis and geometric principles

‘There is no “royal road” to geometry.’

Euclid (c. 300 BC)²⁴ Greek mathematician

This was Euclid’s response to Ptolemy I (King of Egypt), when asked if there was an easier way to solve theorems!

Cephalometric analysis is essentially **applied geometry**; i.e. geometry applied to understanding the structural relationships of the craniofacial complex. Cephalometric analysis has an important place in the diagnosis, treatment planning and treatment result analysis of patients with dentofacial and craniofacial deformities. There is a vast array of cephalometric analyses. Each analysis has some merit, yet will not be applicable in all cases. Therefore, *no claim can be made for the universal application of any specific analysis*. With training, clinicians will become familiar with certain aspects of each analysis, which are useful in the diagnosis of specific facial types and deformities. In addition, time spent in analysing patients using different analyses will *teach the clinician to see*.

When it comes to cephalometric analysis, ‘a little learning is a dangerous thing!’ Clinicians must appreciate the geometrical relationships which constitute each aspect of a cephalometric analysis, and not fall into the trap of attempting to ‘treat to cephalometric norms’. Without such a thorough understanding, it is easy to misdiagnose, thereby leading to incorrect treatment planning.

Description of dentofacial deformities

‘The dentoskeletal structures of the face are like the scaffold over which the soft tissues drape.’²⁵

The facial skeletal framework is concealed under the facial soft tissue drape. Therefore, *in addition* to the primary clinical analysis of the facial soft tissue relationships (see Sections 2 and 3), accurate and detailed evaluation of the underlying dentoskeletal pattern requires analysis of the lateral and PA cephalometric radiographs taken in natural head position (NHP). In highly complex cases, such as severe craniofacial asymmetries or craniofacial syndromes, three-dimensional imaging is also required. It must be emphasized that it is the fundamental underlying relationships of the structural components of the facial skeleton to one another and to the craniofacial complex that need to be established and evaluated, with the aid and clarification afforded in using *selected* parts of *relevant* cephalometric analyses as *diagnostic guides*.

A thorough knowledge of craniofacial dentoskeletal anatomy is paramount to understanding cephalometric analysis (Figures 7.9–7.12). The facial skeleton is formed of a number of combined morphological/structural components. Although these constituent parts are related to one another and to the overlying soft tissues, they may be depicted and illustrated as distinct for descriptive purposes (Figure 7.13). Individual morphological components may deviate from the norm, yet their combination coupled with variation in the overlying soft tissue thickness and

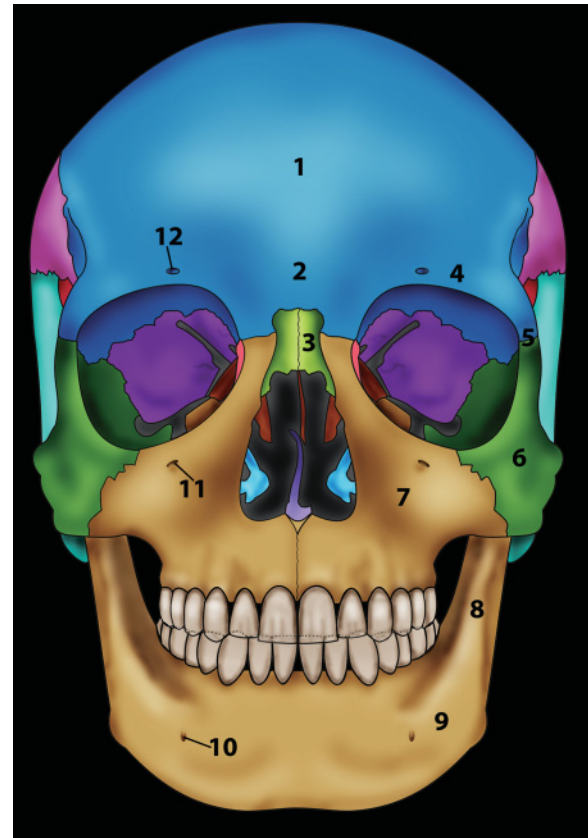


Figure 7.9 Skull (frontal view).

- | | | |
|--------------------------|-------------------------|------------|
| 1 Frontal bone | 7 Maxilla | |
| 2 Glabellar region | 8 Ramus | |
| 3 Nasal bone | 9 Body (corpus) | } Mandible |
| 4 Supraorbital ridge | 10 Mental foramen | |
| 5 Frontozygomatic suture | 11 Infraorbital foramen | |
| 6 Zygomatic bone | 12 Supraorbital foramen | |

dentoalveolar compensation may result in acceptable facial aesthetics and normal dental occlusion. On the other hand, individual components may be more or less within normal range, yet the particular combination of components may lead to poor facial aesthetics and dental malocclusion. Therefore, *measurements of individual morphological components are of no practical significance when assessed in isolation from the overall craniofacial complex*.

It is essential to recognize that most individuals will have variations in the *size*, *shape* and *relative position* of their dentoskeletal structures, and the possible combinations of these morphological components are extremely diverse. Therefore, rather than relying on any simple system of classification, a more effective approach is to describe, sequentially and comprehensively, the arrangement of the various morphological components in relation to one another and to the craniofacial complex. The purpose of this section is to describe the **geometric principles** required to fully appreciate cephalometric analysis, bearing in mind that *clinical evaluation always takes precedence over cephalometric analysis*. Ideally, cephalometric analysis will follow, corroborate and add to the clinical evaluation; where this does

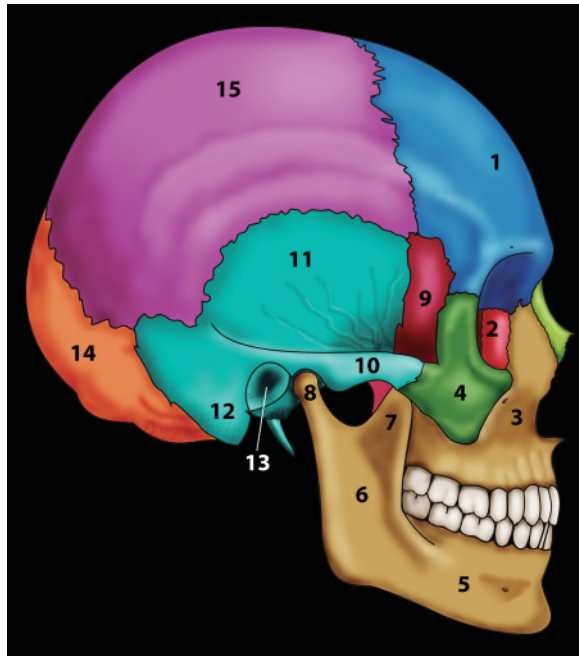


Figure 7.10 Skull (lateral view).

- | | |
|---------------------------------|-----------------------------------|
| 1 Frontal bone | 10 Zygomatic arch |
| 2 Lacrimal bone | 11 Squamous part of temporal bone |
| 3 Maxilla | 12 Mastoid process |
| 4 Zygomatic bone | 13 External acoustic meatus |
| 5 Body | 14 Occipital bone |
| 6 Ramus | 15 Parietal bone |
| 7 Coronoid process | |
| 8 Condylar process | |
| 9 Greater wing of sphenoid bone | |

} Mandible

not occur, further evaluation is required to seek the source of the discrepancy. The results of the various dentoskeletal analyses may be integrated to provide a reasoned and coherent representation of the dentofacial pattern of the individual.

Note

It is important to examine the dentoskeletal relationships using *more than one cephalometric analysis* because, for structural and geometric reasons, a single measurement or analysis may be misleading. The assessment of dentoskeletal relationships should be undertaken using analyses, and thereby measurements, that are *based on different reference planes*. For example, the use of the SNA and SNB angles to assess the sagittal position of the jaws may be misleading because of variations in the orientation of the SN plane. An independent measurement, such as the sagittal position of the jaws in relation to the nasion perpendicular would provide a useful check. When two independent measurements from different analyses reinforce one another, they may be accepted with confidence; but when they do not, the reason for the discrepancy must be sought.

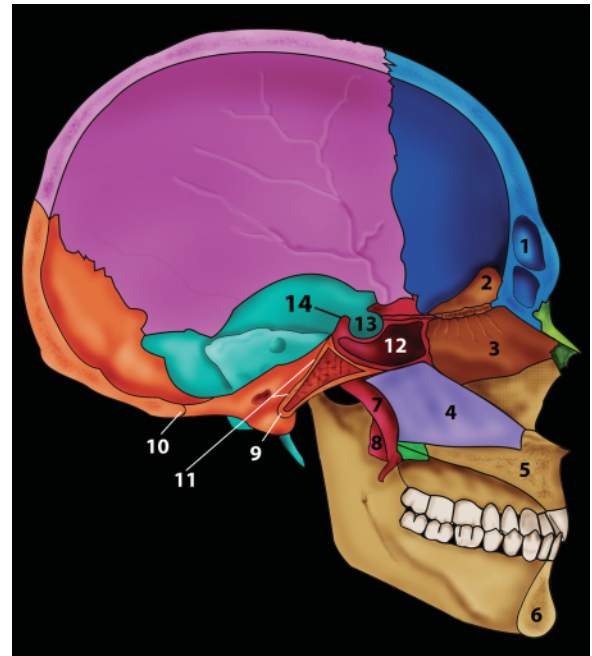


Figure 7.11 Skull (paramedian sagittal section).

- | | |
|---------------------------------------|--|
| 1 Frontal sinus | |
| 2 Crista galli | |
| 3 Perpendicular plate of ethmoid bone | |
| 4 Vomer | |
| 5 Maxilla | |
| 6 Mandibular symphysis | |
| 7 Medial pterygoid plate | |
| 8 Lateral pterygoid plate | |
| 9 Anterior margin | |
| 10 Posterior margin | |
| 11 Clivus | |
| 12 Sphenoidal sinus | |
| 13 Sella turcica | |
| 14 Posterior clinoid process | |

} Foramen magnum

Two commonly used clinical terms require definition:

- **Skeletal pattern:** This term describes the relationship of the maxilla to the mandible in all three planes of space (sagittal, vertical and transverse); it is a primary consideration in clinical diagnosis. It may be referred to as the **skeletal pattern** or **jaw relationship**, although the terms **dental base** and **skeletal base relationship** are also sometimes used. Classification of the skeletal pattern describes the relative position of the underlying skeleton (referred to as **basal bone**) of the maxilla to the mandible, excluding the dentoalveolar processes.
- **Dentoalveolar (apical base) relationship:** The relationship of the maxillary and mandibular dentoalveolar processes (apical bases) to their respective skeletal bases and to the craniofacial skeleton.

Accurate, orderly and objective description of the dentoskeletal structures and their overlying soft tissue relationships will permit the **systematic description** of a presenting deformity.

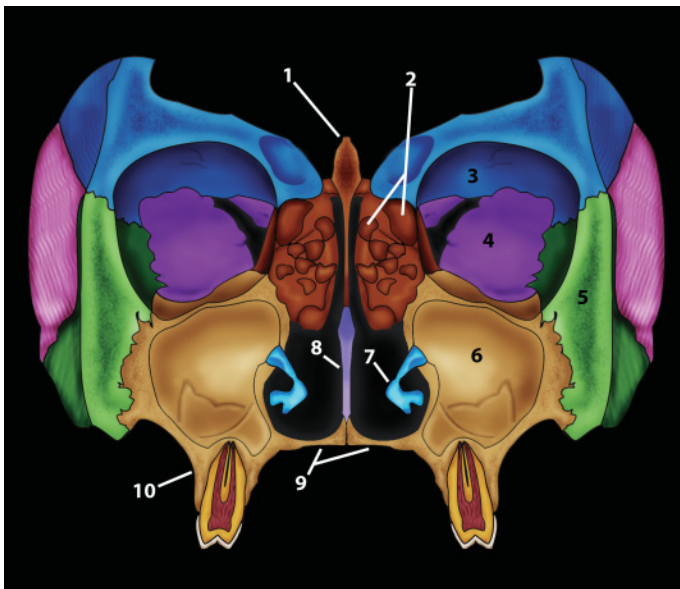


Figure 7.12 Skull (coronal section of anterior facial skeleton).

- | | |
|---------------------------------|--------------------------------|
| 1 Crista galli | 6 Maxillary sinus |
| 2 Ethmoidal air cells | 7 Inferior nasal concha |
| 3 Orbital part of frontal bone | 8 Vomer |
| 4 Greater wing of sphenoid bone | 9 Palatine process of maxilla |
| 5 Zygomatic bone | 10 Alveolar process of maxilla |

Sagittal skeletal relationships

Sagittal positional relationships

Relationship of maxilla, mandible and chin to craniofacial skeleton

Nasion perpendicular (McNamara) (Figure 7.14): With the patient's head oriented in NHP, the most direct method to determine the sagittal position of the maxilla and mandible is to measure the horizontal linear distance to the nasion perpendicular (N-perpendicular), a vertical line perpendicular to the true horizontal, dropped from bony nasion. McNamara's original data was based on the Frankfort Horizontal plane rather than the true horizontal plane. Points anterior to N-perpendicular are assigned a positive value, and posterior a negative value. In white Caucasian patients:²⁶

- Maxillary point A is on or slightly ahead of nasion perpendicular (0 to +1 mm).
- Mandibular point B is 2–3 mm behind nasion perpendicular.
- A-B difference (horizontal distance between points A and B when both are projected onto the true horizontal) is approximately 4 mm.
- Hard tissue pogonion is:
 - –4 to 0 mm behind N-perpendicular (in adult women)
 - –2 to +5 mm to N-perpendicular (in adult men).

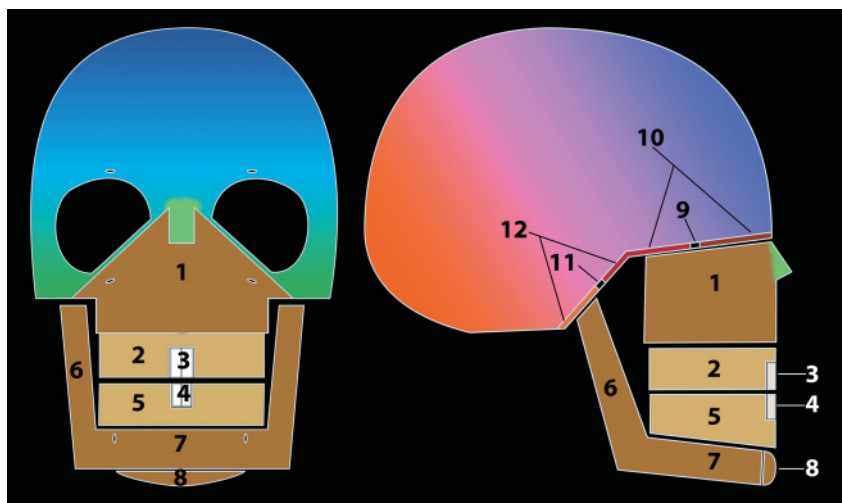


Figure 7.13 Free body diagrams depicting the structural components of the craniofacial complex.

- | | |
|----------------------------|------------------------------------|
| 1 Nasomaxillary complex | 7 Mandibular body (corpus) |
| 2 Maxillary dentoalveolus | 8 Mandibular symphysis (bony chin) |
| 3 Maxillary incisors | 9 Sphenoethmoidal synchondrosis |
| 4 Mandibular incisors | 10 Anterior cranial base |
| 5 Mandibular dentoalveolus | 11 Sphenooccipital synchondrosis |
| 6 Mandibular ramus | 12 Posterior cranial base |

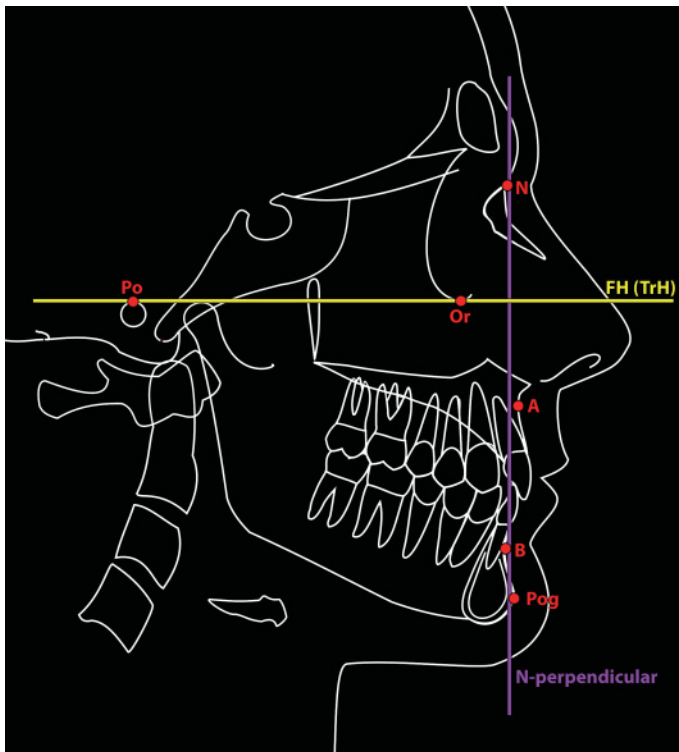


Figure 7.14 The nasion perpendicular is a vertical line perpendicular to the Frankfort Horizontal plane, or ideally the true horizontal plane (TrH), dropped from bony nasion.

Note

Facial divergence has an effect on the relationship of the maxilla and mandible to the N-perpendicular. Some individuals with well-proportioned faces and normal dental occlusion may have posteriorly (usually northern Europeans) or anteriorly (usually black and Far Eastern ethnic backgrounds) divergent facial profiles. In individuals with posteriorly divergent profiles, points A and B may be significantly behind N-perpendicular, whereas in individuals with anteriorly divergent profiles, points A and B may be in front of N-perpendicular; in both cases the facial profile aesthetics and dental occlusal relationships may be normal.

Projected A-B difference (modified from Burstone) (Figure 7.15A–C): An important first step used to establish whether a sagittal jaw discrepancy exists is to measure the horizontal distance between points A and B as projected onto the true horizontal plane. An A-B difference greater than 6 mm (A ahead of B) or less than –4 mm (B ahead of A) indicates a discrepancy. If a discrepancy is found in the A-B difference, then the position of the maxilla and mandible to the N-perpendicular may be compared in order to assess which jaw is at greater fault. The original method described by Burstone¹³ used the constructed Frankfort Horizontal plane rather than a true horizontal plane.

Craniofacial balance line and craniofacial angle (Delaire) (Figure 7.16): The ‘superior cranial base line’ (**Delaire horizontal**) is constructed by joining the M-point with the apex of the posterior clinoid process (Pcp). The ‘craniofacial balance line’ (**Delaire vertical**) is a vertical line constructed from just posterior to point M, perpendicular to the Delaire horizontal line, and

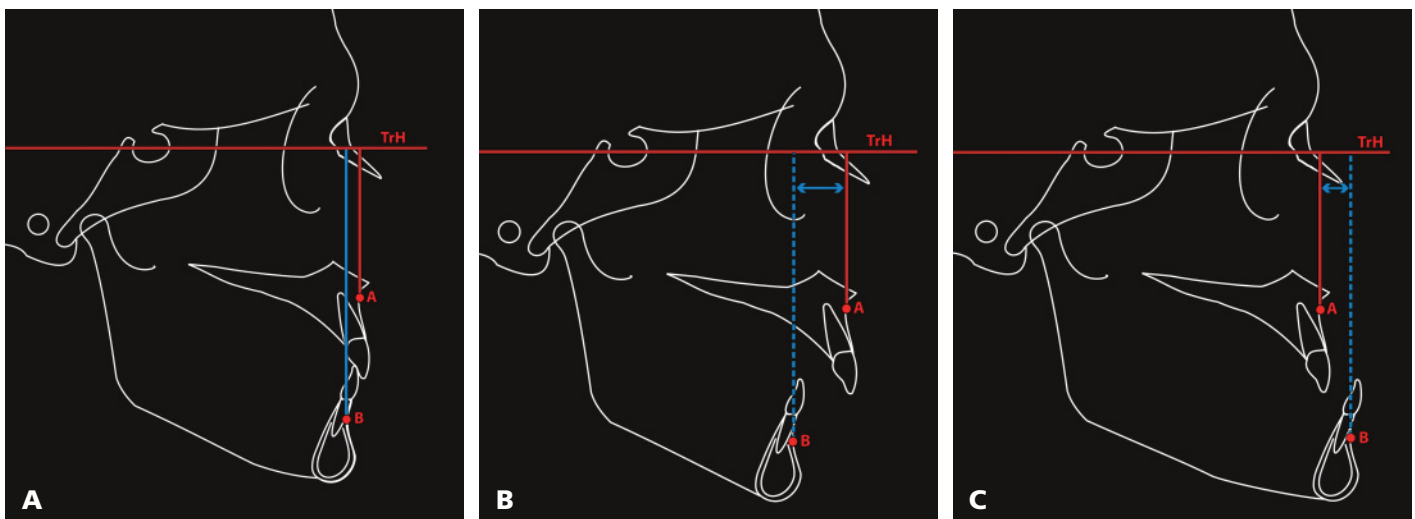


Figure 7.15 The horizontal distance between projections of maxillary A-point and mandibular B-point onto the true horizontal (TrH) plane provide an indication of sagittal jaw discrepancy. (A) ‘Ideal’ projection of A ahead of B by ~ 4 mm (skeletal Class I). (B) A ahead of B by more than 6 mm indicates a Class II jaw discrepancy. (C) B ahead of A by more than 4 mm indicates a Class III jaw discrepancy.

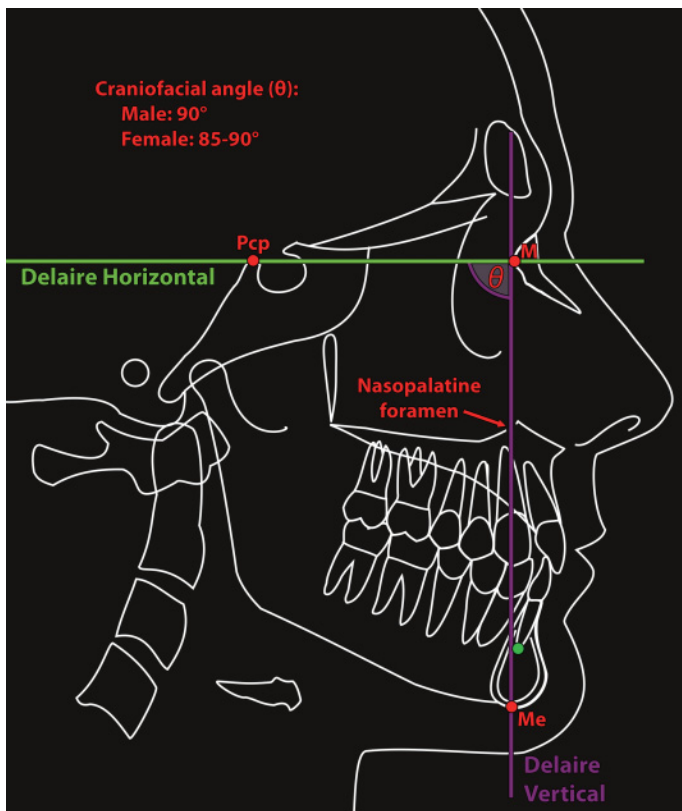


Figure 7.16 The Delaire craniofacial analysis and craniofacial angle.

determines the sagittal position of the maxillary and mandibular skeletal bases. In an 'ideal' face the Delaire vertical line runs through the:^{6,7}

- **Nasopalatine foramen** (determines the sagittal position of the maxilla).
- **Root of the maxillary canine**, at the junction of the apical and middle thirds (indicates sagittal position of maxillary dentoalveolus).
- **Apex of the mandibular incisor** (indicates sagittal position of mandibular dentoalveolus).
- **Menton** (determines the sagittal position of the mandible).

The **craniofacial angle** is the posterior inferior angle formed by the intersection of the Delaire vertical and horizontal lines. It helps to determine the sagittal position of the maxillary and mandibular skeletal bases relative to the cranial base. Normal Caucasian adult values are:^{6,7}

- Male: 90°.
- Female: 85–90°.

Relationship of maxilla, mandible and chin to cranial base

The angles SNA and SNB were originally described by the orthodontist Richard R Riedel (1952),²⁰ and form part of the Steiner cephalometric analysis (1953),⁸ introduced by the orthodontist Cecil C Steiner (Figure 7.17).

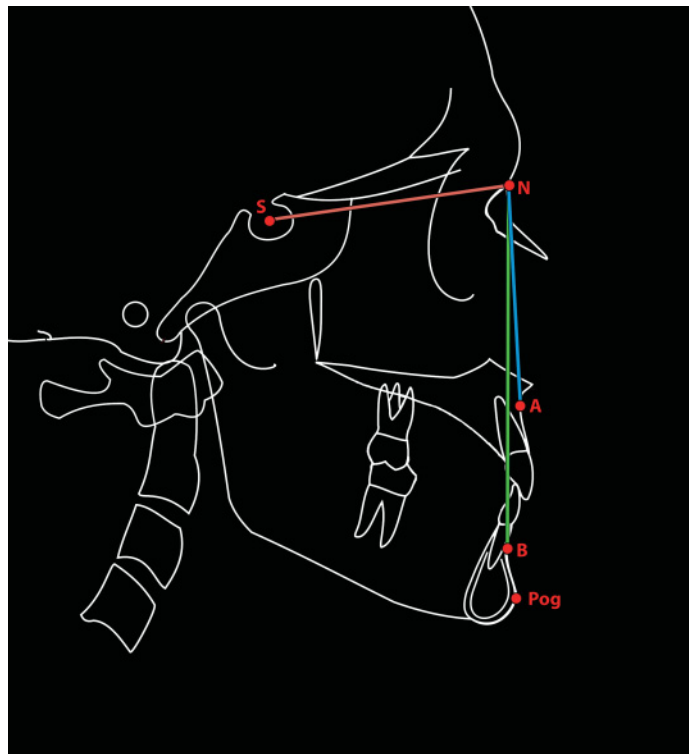


Figure 7.17 The SNA and SNB angles demonstrate the sagittal position of the maxillary and mandibular apical bases, respectively, relative to the anterior cranial base.

SNA angle ($82^\circ \pm 3^\circ$): relates the sagittal position of the maxillary apical base (A-point) to the anterior cranial base (SN). The SNA angle provides an *indication* of the sagittal position of the maxilla relative to the anterior cranial base (Figure 7.18).

SNB angle ($79^\circ \pm 3^\circ$): relates the sagittal position of the mandibular apical base (B-point) to the anterior cranial base (SN). The SNB angle provides an *indication* of the sagittal position of the mandible relative to the anterior cranial base.

When assessing sagittal jaw position using the angles SNA and SNB, the following factors must be borne in mind:

- **Variations in A-point and B-point:** Although the angles SNA and SNB provide a good indication of the relative sagittal positions of the maxilla and mandible, it must be emphasized that A and B points are *alveolar points* and do not necessarily represent the true position of the skeletal bases. In addition, these points may vary with growth and due to the alveolar bone remodelling that may occur with orthodontic treatment changes in the inclination of the incisor teeth. Nevertheless, the angles SNA and SNB give a useful indication of the degree of prognathism or retrognathism of the jaws at any one time.
- **Variation in the position or orientation of the SN plane:** In patients with dentofacial and/or craniofacial deformities, there is always the possibility of deviations from the norm in the inclination (or sagittal cant) of the cranial base, as well as in the position of the jaws. Therefore, abnormal cephalometric measurements relating the jaws to the cranial base

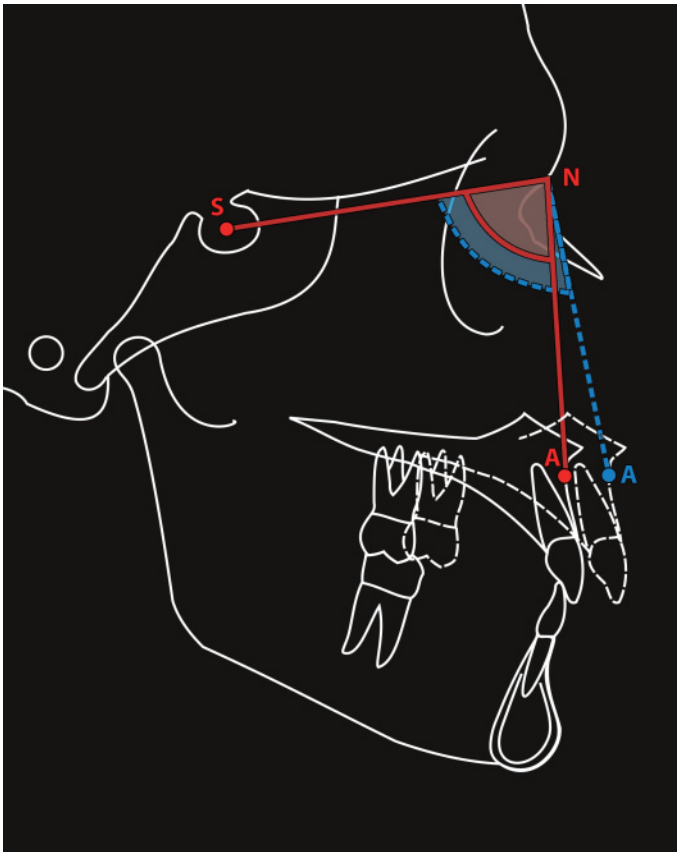


Figure 7.18 An increase in the SNA angle may indicate protrusion of the maxillary dentoalveolus.

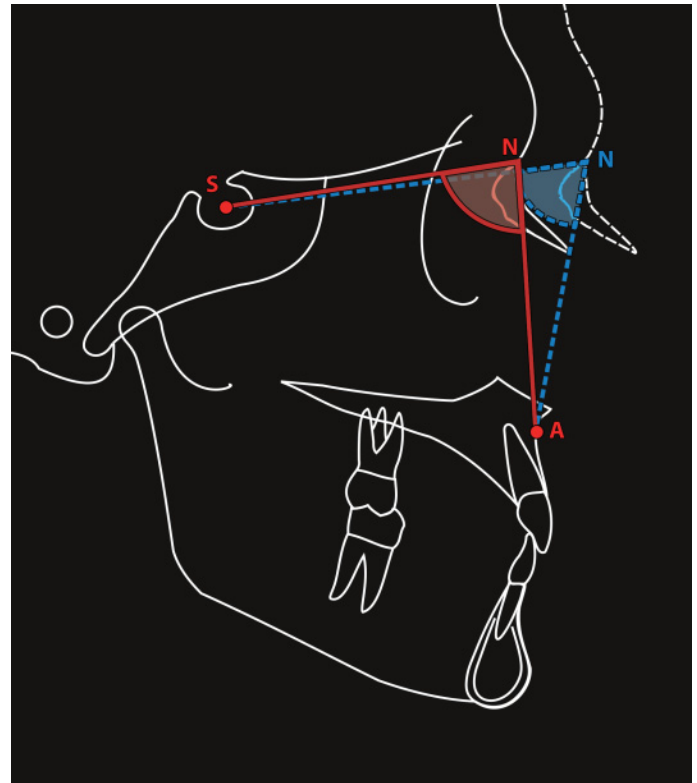


Figure 7.19 The SNA angle will reduce if nasion is more forward in position.

may be due to deviations in the cranial base (the position of sella, nasion or both), rather than in the position of the maxilla or mandible. The normal inclination of the SN plane to the Frankfort Horizontal plane (or ideally the true horizontal plane) is $6-7^\circ$. The SNA and SNB angles may only be used if the SN plane is normally oriented or after correction for the inclination of the SN plane to the true horizontal plane. If nasion is more forward in position, the SNA angle is decreased, and vice versa (Figure 7.19). Therefore, in these circumstances the angle ANB may be adjusted, to some extent, as follows: for every 1° that angle SNA is below the average value of 82° , 0.5° is added to the angle ANB. For every 1° that it is above the average, subtract 0.5° from the angle ANB. Variations in the vertical position of sella will affect the values of angles SNA and SNB, but not the angle ANB (Figure 7.20).

- **Effect of facial divergence on SNA and SNB** (Figure 7.21): Variation in the sagittal position of points A and B may be due to the general slope of the face, i.e. facial divergence. In a posteriorly divergent face, the SNA and SNB angles will be reduced from the average, and in an anteriorly divergent face, the angles will be increased from the average. However, the SNA-SNB difference, or ANB angle, should remain average.

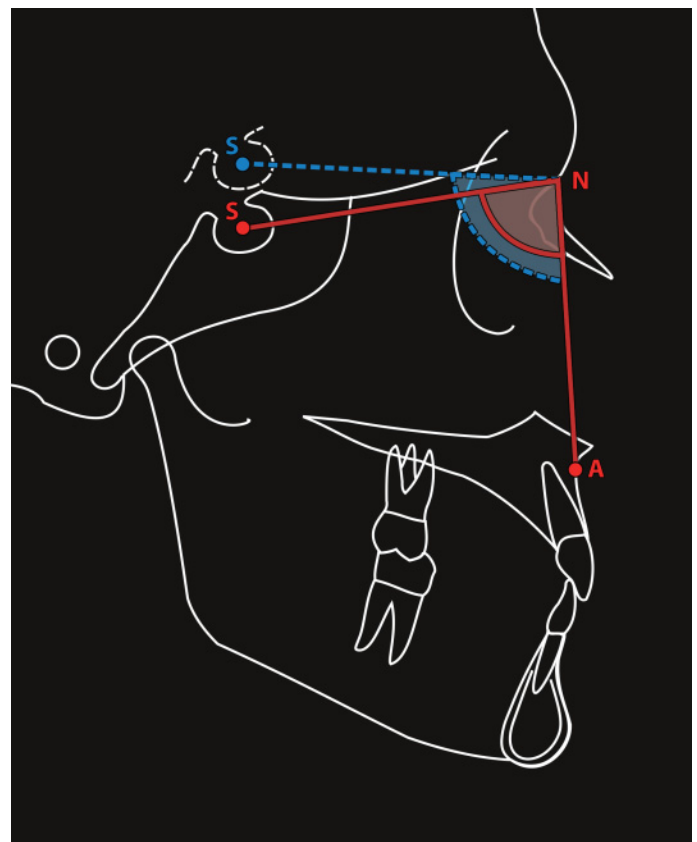


Figure 7.20 Variations in the vertical position of sella will affect the values of angles SNA and SNB.

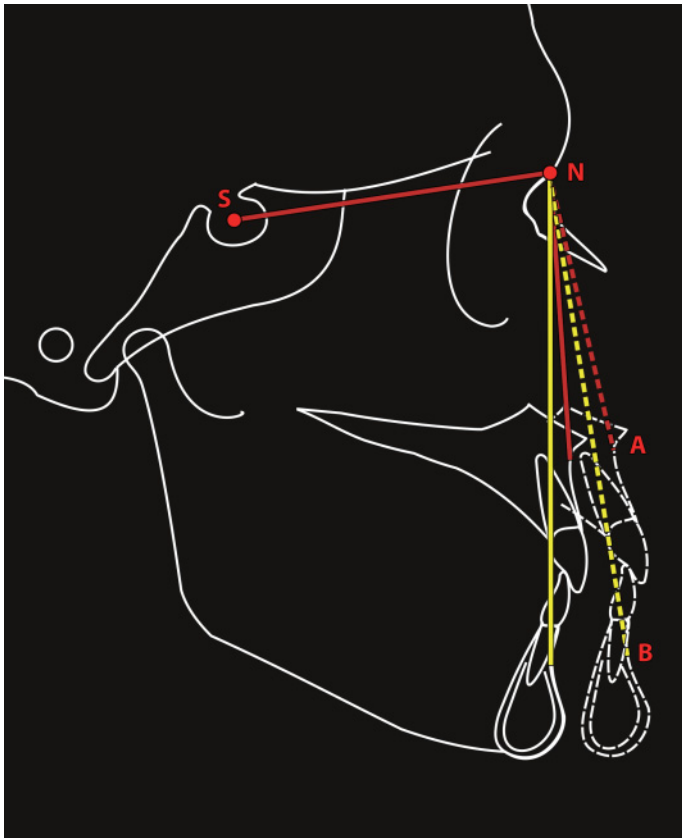


Figure 7.21 Anterior facial divergence tends to increase both the SNA and SNB angles, though the ANB angle may remain within normal limits.

SND angle (76–77°): The SND angle was described by Steiner.⁹ Point 'D' is the centre of the body of the symphysis and is estimated visually. The SND angle provides an assessment of the *sagittal position of the mandibular skeletal base* in relation to the anterior cranial base. Although the angle SNB is often used to provide an *indication* of the sagittal position of the mandible, point B is actually a dentoalveolar and not a skeletal point. Therefore, the angle SNB demonstrates the position of the mandibular dentoalveolar process (apical base) to the anterior cranial base, whereas the angle SND more accurately expresses the relationship of the mandibular skeletal base to the anterior cranial base.

SN-Pog angle ($80^\circ \pm 3^\circ$): This angle is formed between the most anterior point on the bony chin (pogonion) and the SN plane. It is important to compare the value of SNB to SN-Pog. In patients with a well-developed chin but mandibular dentoalveolar (apical base) retrusion, the facial profile may be acceptable even though the dentoalveolar relationship is unfavourable. This relationship is common in Class II division 2 type cases. If SN-Pog is smaller than SNB, the patient is likely to have an excessively recessive bony chin in the sagittal plane.

Note

In analysing the sagittal position of the mandible, it is *inaccurate and imprecise to place undue reliance on any single measurement* due to the anatomical variations of the anterior aspect of the mandible, its dentoalveolar process and the chin. The angles SNB, SND and SN-Pog must be assessed in order to compare the sagittal position of the dentoalveolar process, mandibular skeletal base and chin, respectively (Figure 7.22A,B).

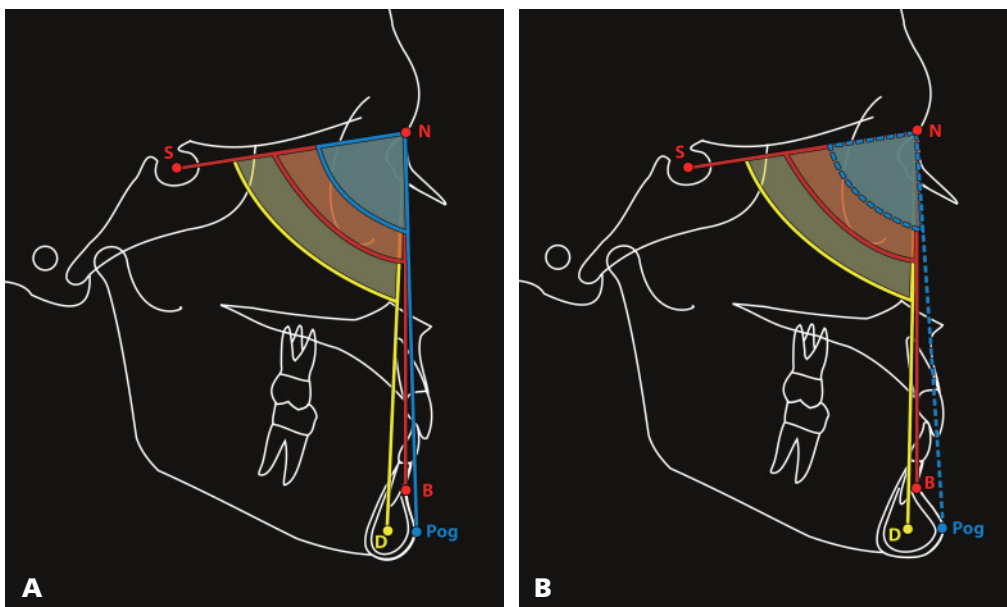


Figure 7.22 Comparing (A) and (B) the SNB angle remains the same; the SND angle varies only slightly, but the SN-Pog angle has increased significantly in (B) due to sagittal chin excess. All three angles should be compared when analysing the anterior aspect of the mandible.

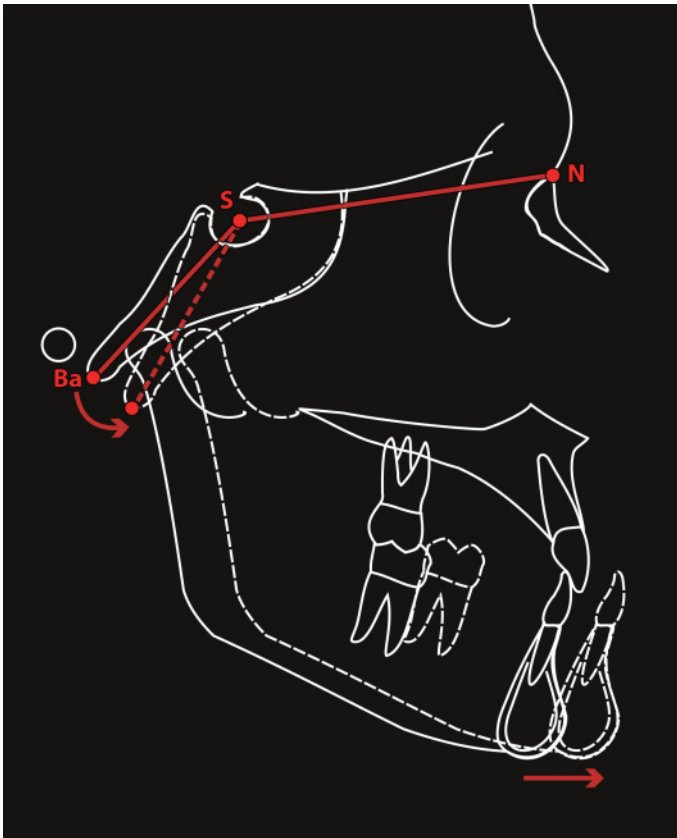


Figure 7.23 A reduction in the cranial base (saddle) angle may result in mandibular excess due to a forward position of a normal sized mandible.

Cranial base (saddle) angle ($130^\circ \pm 5^\circ$) (Figure 7.23): The 'saddle angle' is so termed as the angle centres at sella, which is the midpoint of the sella turcica (Latin for 'Turkish saddle'). The saddle angle (N-S-Ba) is the angle formed between the anterior and posterior cranial base; it is effectively a measure of the 'bend' between the anterior and posterior cranial base. It is measured as the anterior inferior angle formed by the intersection of the SN line, which represents the anterior cranial base and the S-Ba line, which represents the posterior cranial base.²⁷ An *increased* saddle angle indicates a posterior position of the glenoid fossa and mandibular condyle, thereby a posteriorly positioned mandible (mandibular retrognathia) in relation to the cranial base, unless compensated by a more acute gonial angle and increased mandibular length; conversely, a *reduced* saddle angle indicates an anterior position of the glenoid fossa and mandibular condyle, thereby leading to mandibular prognathism, unless compensated by an increased gonial angle and reduced mandibular length. (If basion is difficult to identify on a lateral cephalometric radiograph, articulare may be used instead; normal value for N-S-Ar is $125^\circ \pm 5^\circ$.)

Relationship of maxilla to mandible (skeletal pattern)

The *sagittal* relationship of the mandible to the maxilla may be described as skeletal Class I, II or III:

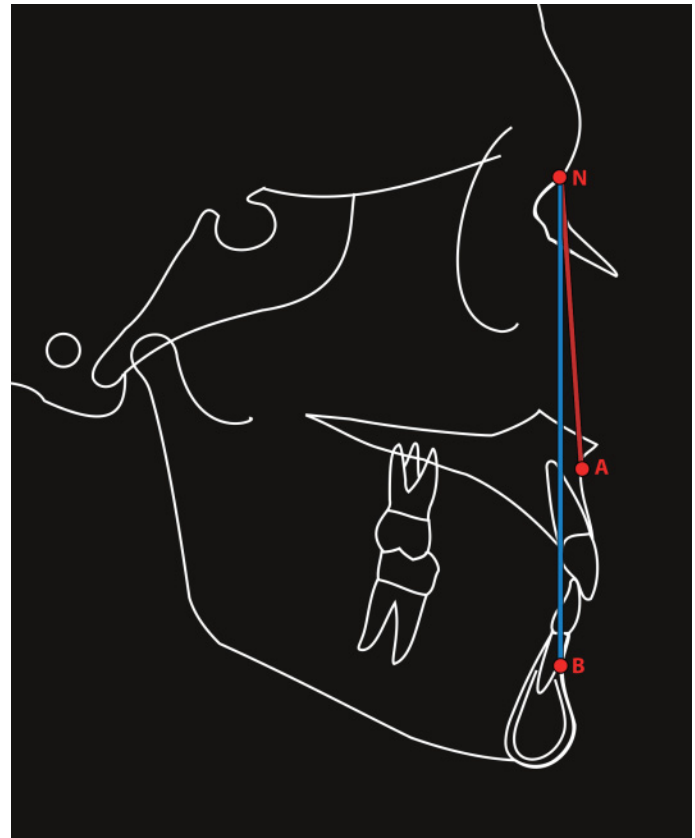


Figure 7.24 The ANB angle represents the difference between the SNA and SNB angles, providing an indication of the sagittal discrepancy between the maxillary and mandibular apical bases.

- **Skeletal Class I:** The maxillary and mandibular skeletal bases are in a normal sagittal relationship to one another; the maxillary skeletal base is 2–3 mm anterior to the mandibular.
- **Skeletal Class II:** There is *relative* maxillary prominence in the sagittal plane, i.e. in occlusion, the mandible is positioned further back in relation to the maxilla than in skeletal Class I.
- **Skeletal Class III:** There is *relative* mandibular prominence in the sagittal plane, i.e. in occlusion, the mandible is positioned further forward in relation to the maxilla than in skeletal Class I.

It must be noted that the *skeletal Class* relates the maxillary and mandibular skeletal bases to each other and not to the face. In other words the classification 'skeletal Class III' does not define whether the mandible is prognathic, the maxilla retrognathic or a combination of the two. An indication of the **range of severity** of skeletal Class II and III relationships is provided by the ANB angle.

ANB angle ($3^\circ \pm 1^\circ$): The ANB angle represents the difference between the SNA and SNB angles, providing an indication of the sagittal discrepancy between the maxillary and mandibular apical bases (Figure 7.24). The ANB angle is positive if point A lies anterior to NB. If NA and NB coincide, the ANB angle is

zero. If point A lies posterior to NB, ANB will be negative. The skeletal pattern is described as:

- Class I: the ANB angle is in the range 2–4°.
- Class II: if ANB angle greater than 4°.
- Class III: if ANB angle less than 2°.

When assessing sagittal skeletal pattern using the angle ANB, the following factors must be borne in mind:

- **Anatomical variation in the position of nasion** (Figure 7.25): Variation in the position of nasion may give misleading values of ANB angle.
- **The influence of vertical face height on angle ANB** (Figure 7.26): With the same ANB angle, the greater the anterior face height, the larger the sagittal distance between A-point and B-point, due to greater divergence of the NA and NB lines from nasion.
- **Relationship of ANB angle and dental occlusion** (Figure 7.27): The sagittal occlusal and skeletal relationships do not always match and must be assessed independently of one another. An apical base relationship beyond the normal range (ANB angle normal range: 2–4°) may be associated with a normal Class I dental occlusion, if there has been dentoalveolar compensation (see Chapter 22) for the underlying skeletal pattern. Conversely, occlusal malrelationships

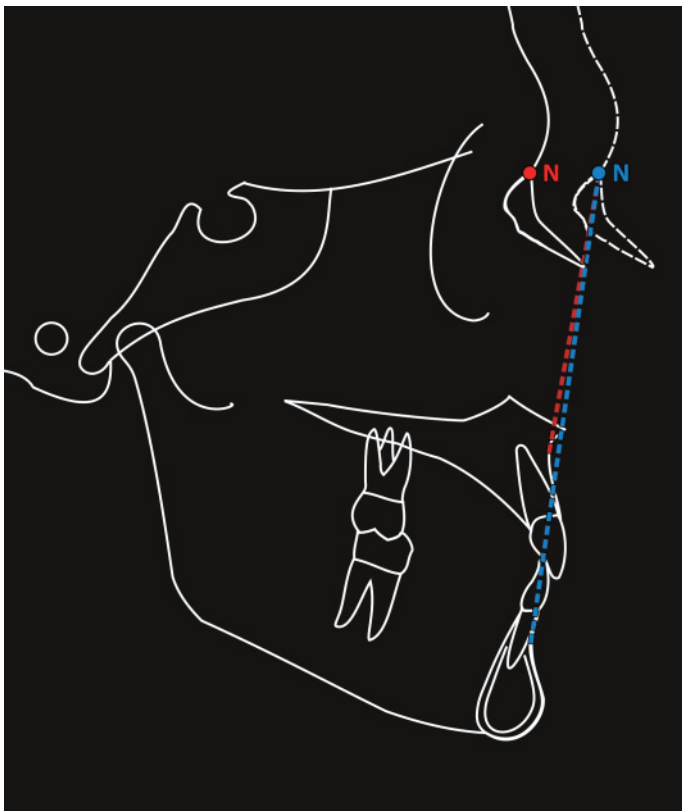


Figure 7.25 Variation in the position of nasion may give misleading values of ANB angle; an anterior position of nasion may give a negative ANB value despite a normal relationship of the apical bases.

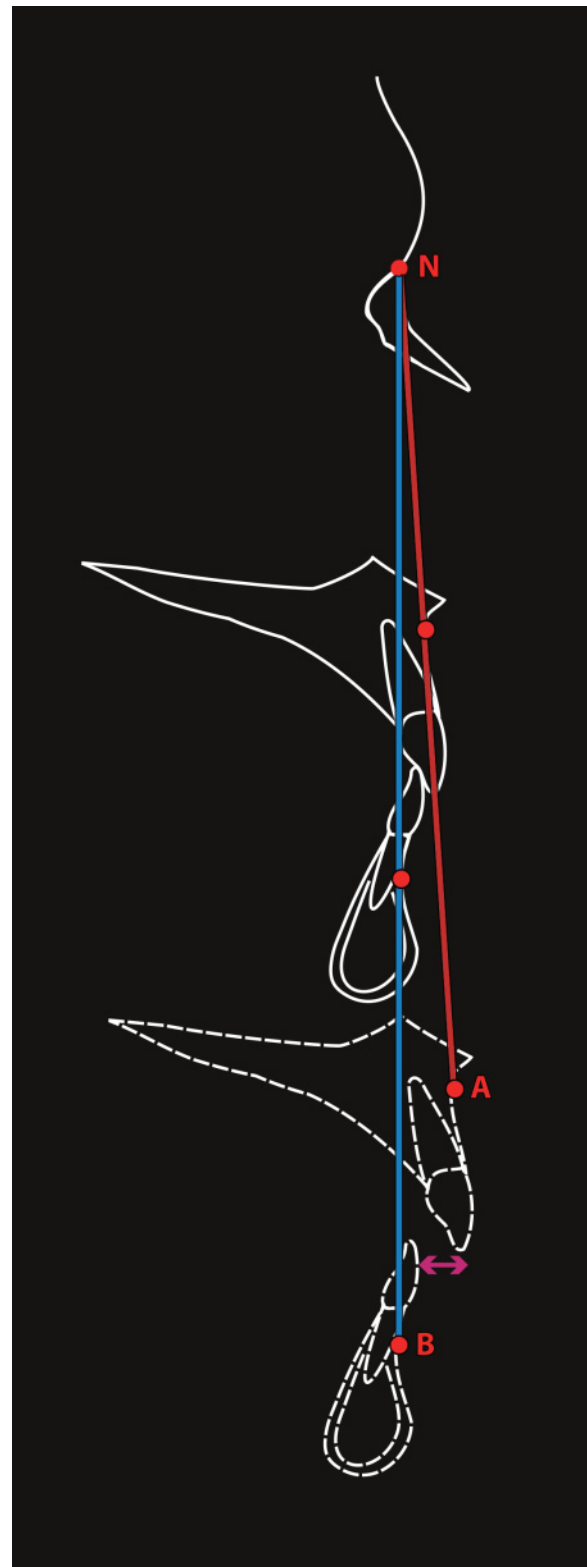


Figure 7.26 With the same ANB angle, the greater the anterior face height, the larger the sagittal distance between A-point and B-point, i.e. the ANB angle becomes a less reliable indicator of the jaw relationship as face height increases.

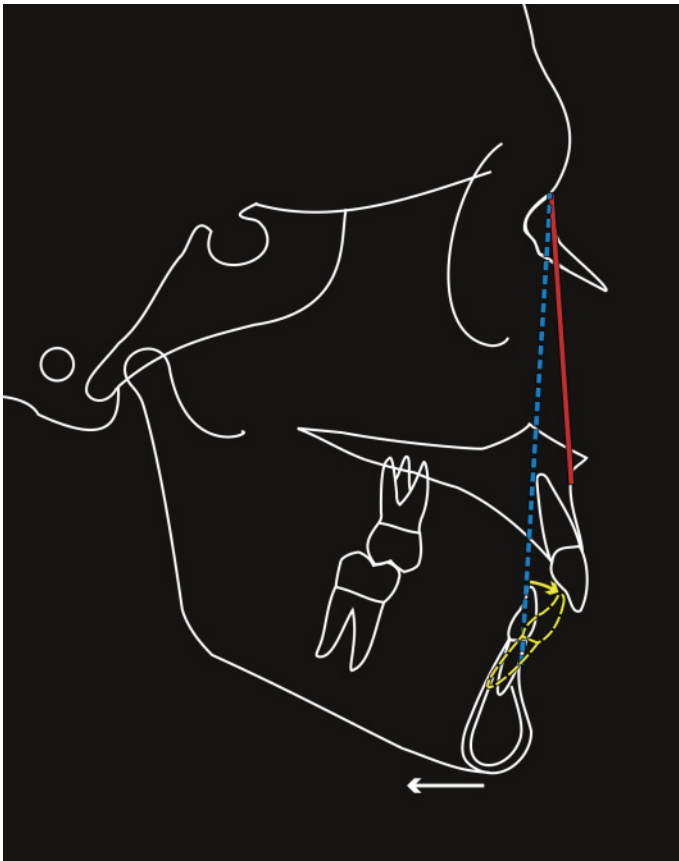


Figure 7.27 A Class I incisor relationship due to dentoalveolar compensation with proclination of the mandibular incisor teeth, despite a skeletal Class II jaw relationship (increased ANB angle).

may occur on a normal skeletal Class I pattern, if the dental inclinations are unfavourable.

- **The influence of sagittal rotation of the maxillomandibular complex on angle ANB:** Sagittal rotation of the maxillomandibular complex, around the transverse axis, will have an effect on the relative position of A- and B-points to nasion. Forward (anticlockwise) rotation will have a decreasing effect on the ANB angle (Figure 7.28A); conversely, backward (clockwise) rotation will have an increasing effect on the ANB angle (Figure 7.28B). Such rotations do not have an effect on the occlusal relationship or the Wits appraisal (see below).

The ANB angle relates the position of the jaws to nasion, which is a structure outside the maxillomandibular complex. There are two methods to assess the sagittal relationship of the jaws to one another, without consideration of outside structures: the Ballard 'conversion' method, and the Wits appraisal.

Ballard conversion (Ballard) (Figure 7.29): This method was devised by the orthodontist Clifford Ballard,²⁸ and uses the *incisor overjet as the indicator of the relative position of the maxilla to the mandible*. The aim is to eliminate any dentoalveolar compensation for the underlying skeletal pattern by correcting the inclination of the incisors to their 'ideal' inclination. The **residual incisor overjet** is thereby used as an indicator of the sagittal skeletal discrepancy.

The method is useful as an indicator of sagittal skeletal discrepancy, but becomes less reliable if vertical skeletal discrepancies are also present. In addition, the accepted 'norms' used for incisor inclinations and the mandibular plane angle must be

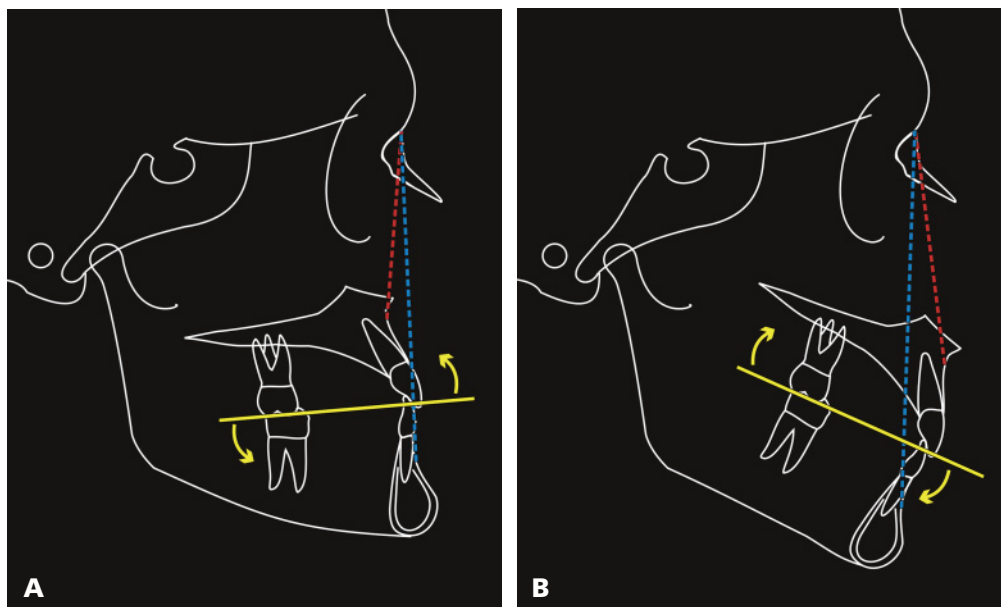


Figure 7.28 (A) Forward (anticlockwise) rotation of the bimaxillary complex will have a decreasing effect on the ANB angle. (B) Conversely, backward (clockwise) rotation will have an increasing effect on the ANB angle.

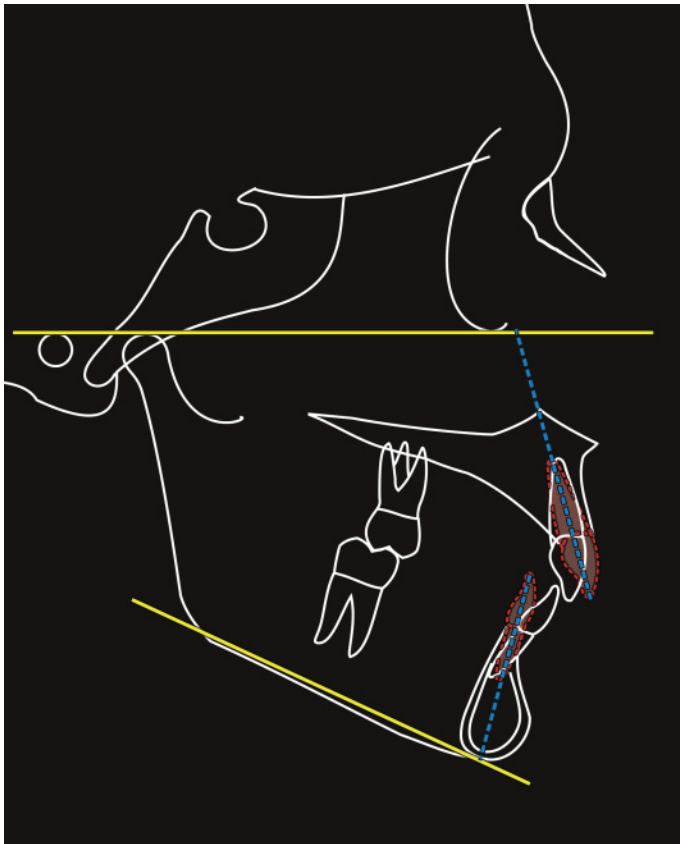


Figure 7.29 The Ballard conversion method to evaluate sagittal jaw discrepancy: The outlines of the maxilla, maxillary incisors, mandible and mandibular incisors are traced over the lateral cephalometric radiograph. The long axes of these teeth are drawn from incisal tip to root apex. The root centroid (centre of resistance) is identified as a pivot point, or point of rotation, about one-third to one-half of the root length from the root apex. The maxillary and mandibular incisor inclinations are corrected by rotating around the root centroid until the 'ideal' inclination is reached. The **residual incisor overjet** is taken as a reflection of the sagittal skeletal discrepancy, i.e. an increased overjet signifies a Class II skeletal pattern, and a reduced or reverse overjet a Class III skeletal pattern.

ethnicity specific. The main drawbacks of this method are the difficulty in tracing the roots of the incisor teeth, particularly the mandibular incisors, and the assumption that the incisors have a fixed root centroid positioned approximately one-third to one-half of the root length from the root apex.

'Wits' appraisal (Jacobson): Another method used to describe the relationship of the jaws to each other is the Wits appraisal, originally described by Jenkins²⁹ and later popularized by Jacobson.^{30,31} The procedure involves constructing perpendiculars from maxillary A-point and mandibular B-point to the functional occlusal plane (FOP, drawn through the region of the overlapping cusps of the first permanent molars and the premolars), establishing points AO and BO, respectively, and measuring the distance along the functional occlusal plane between the points AO and BO. The linear measurement between AO and BO provides an indication of the sagittal discrepancy between the maxilla and mandible (Figure 7.30A).

The mean values are:

- Female: BO and AO coincide; range: 0 ± 2 mm.
- Male: BO is 1 mm ahead of AO; range: -1.0 ± 2 mm (males are slightly more Class III than females).

Figure 7.30B shows the effect of a skeletal Class II pattern and Figure 7.30B shows the effect of a skeletal Class III pattern on the Wits reading. The greater the Wits reading deviates from -1.0 mm in men and 0 mm in women, the greater the extent of the sagittal skeletal discrepancy. The advantages of this technique are its simplicity and that it is not influenced by the cranial base. The drawback is that the functional occlusal plane is not easy to locate, and variation in its orientation will affect the estimate of the skeletal pattern from the AO and BO projections to it.

Size relationships of maxilla and mandible

Ratio of midfacial to mandibular length (McNamara) (Figure 7.31): The orthodontist Egil P Harvold initially developed standards for the 'unit length' of the maxilla and mandible, using data from the Burlington growth study of the University of Toronto.³² The difference between the maxillary and mandibular unit lengths provides an indication of the 'size discrepancy' between the jaws. The analysis was subsequently developed as part of the McNamara analysis, using data derived from the Bolton growth study in Ann Arbor, Michigan.²⁶

- **Midfacial unit length:** Measured from condyion to 'lower ANS' (defined as the point on the lower shadow of the anterior nasal spine where the projecting spine is 3 mm thick). 'Midfacial' is a more accurate term than 'maxillary' in this context, as condyion is a point on the mandible.
- **Mandibular unit length:** Measured from condyion to gnathion.
- **Midface-mandibular length differential:** Determined by subtracting the midfacial length from the mandibular length. This 'size differential' will depend on the stature of the individual:
 - Small individuals: difference should be 20–24 mm
 - Medium-sized individuals: difference should be 25–28 mm
 - Large individuals: difference should be 29–33 mm.

It must be stressed that the terms 'small', 'medium' and 'large' essentially correspond to mixed dentition, adult female and adult male, respectively. However, the terms small, medium and large are preferred due to the inherent variations in size and stature in individuals of different age and sex. Figure 7.32 demonstrates the relationship between midfacial length (effective maxillary length), mandibular length and lower anterior facial height.³³ Any specific midfacial length will correspond to a specific mandibular length and lower anterior facial height, within a given range (Table 7.8). This relationship is generally linear and depends on the *size* rather than the age or sex of the individual.

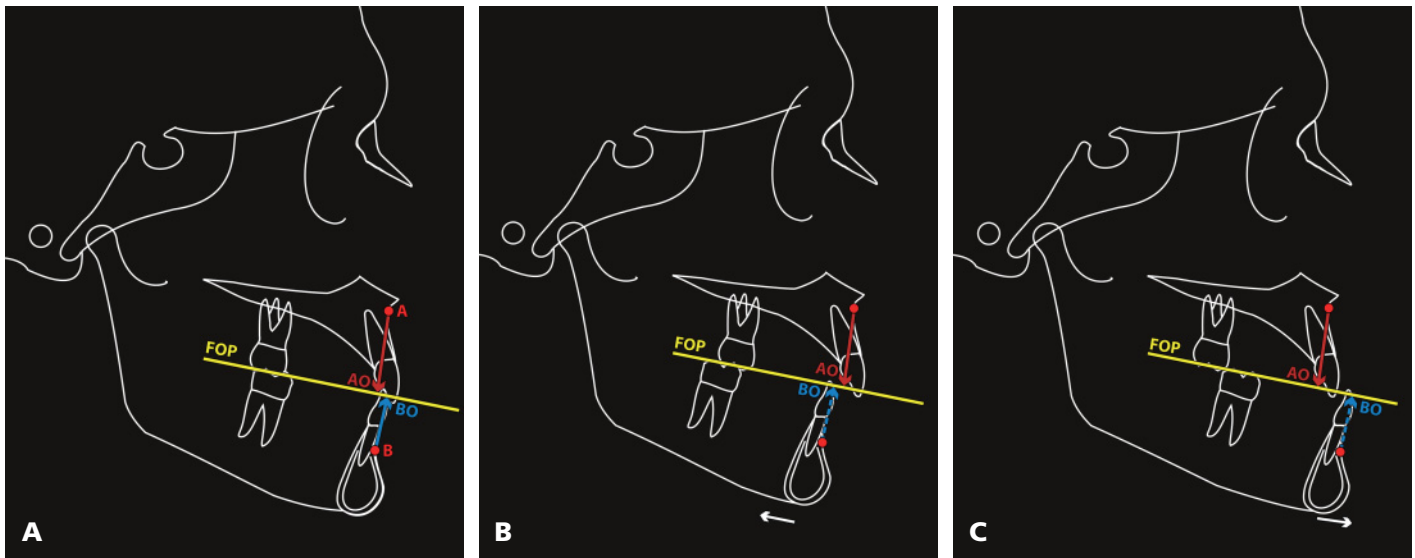


Figure 7.30 (A) The Wits appraisal of sagittal jaw discrepancy involves constructing perpendiculars from maxillary A-point and mandibular B-point to the functional occlusal plane (FOP), establishing points AO and BO respectively, and measuring the distance along the FOP between the points AO and BO. (B) In a skeletal Class II jaw relationship, point BO will be located behind point AO (a positive Wits reading). (C) In a skeletal Class III jaw relationship, point BO will be located ahead of point AO (a negative Wits reading).

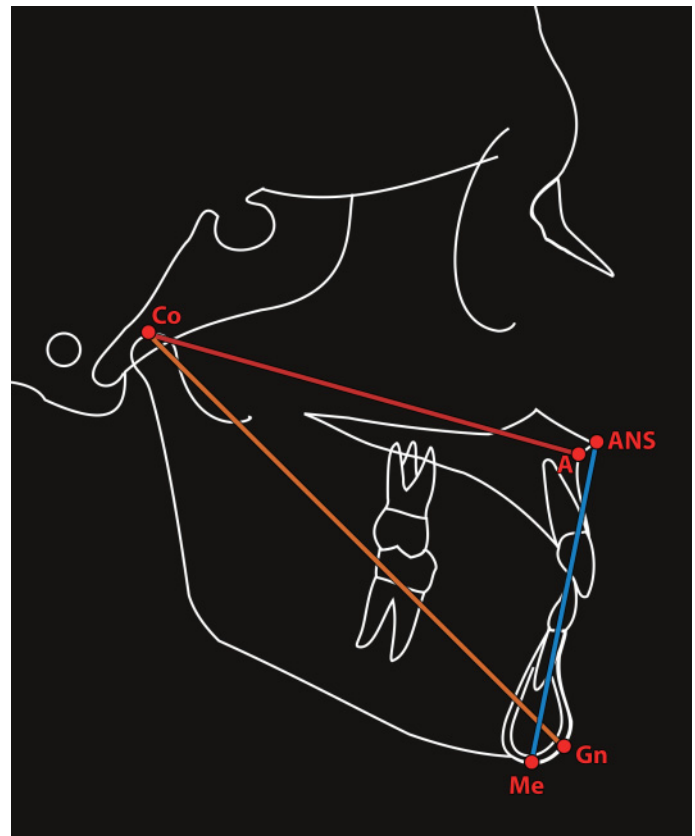


Figure 7.31 The difference between the maxillary (Co-A) and mandibular (Co-Gn) unit lengths provides an indication of the size discrepancy between the jaws. In a well-proportioned face, both values are related to the lower anterior face height (LAFH) (see Table 7.8).

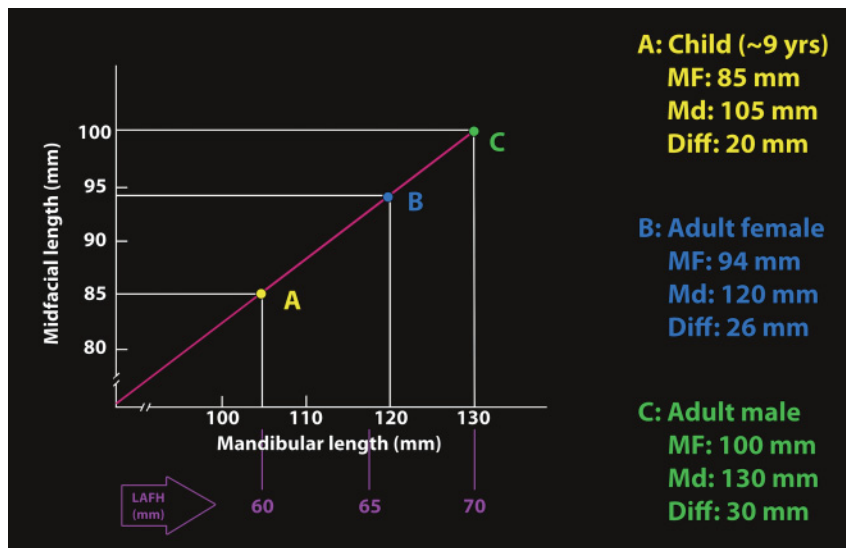


Figure 7.32 The relationship between midfacial length (effective maxillary length), mandibular length and lower anterior facial height (LAFH) is approximately linear, depending on the size rather than the age or sex of an individual. Any specific midfacial length will correspond to a specific mandibular length and LAFH, within a given range. MF, midfacial length; Md, mandibular length; Diff, midface-mandibular length differential. (Adapted from McNamara and Brudon³³ with kind permission of Professor James A McNamara Jr and Needham Press.)

Table 7.8 Normative standards in McNamara Analysis

Midfacial length (mm) (Co-A point)	Mandibular length (mm) (Co-Gn)	Lower anterior facial height (mm) (ANS-Me)
80	97–100	57–58
81	99–102	57–58
82	101–104	58–59
83	103–106	58–59
84	104–107	59–60
85	105–108	60–62
86	107–110	60–62
87	109–112	61–63
88	111–114	61–63
89	112–115	62–64
90	113–116	63–64
91	115–118	63–64
92	117–120	64–65
93	119–122	65–66
94	121–124	66–67
95	122–125	67–69
96	124–127	67–69
97	126–129	68–70
98	128–131	68–70
99	129–132	69–71
100	130–133	70–74
101	132–135	71–75
102	134–137	72–76
103	136–139	73–77
104	137–140	74–78
105	138–141	75–79

Sagittal dentoalveolar relationships

The term sagittal ‘skeletal pattern’ refers to the sagittal relationship of the basal bone of the maxilla and mandible. The alveolar bone, which invests the teeth, thereby forming the **dentoalveolar process**, is supported by the basal bone. However, the sagittal relationship between the maxillary and mandibular dentoalveolar processes is not necessarily the same as that between their respective basal bones.

Dentoalveolar (dental and alveolar bone) position may, to a limited extent, be independent of its supporting basal bone and skeletal relationship. The reason is that tooth position is not determined entirely by jaw position. Other factors, in particular those related to the soft tissue environment of the teeth, may cause the teeth to erupt and/or move away from their correct inclinations. The alveolar bone develops to support the teeth and therefore may be, within a limited range, slightly different in position from the basal bone. It is necessary to determine both the **inclination** and sagittal **position** of the incisor teeth in relation to the craniofacial complex.

Inclination of the maxillary incisors

The inclination of the maxillary incisors is important both in terms of occlusal function and dentofacial aesthetics. The long axis of the maxillary incisor from the incisal tip to the root apex is drawn and extended to meet a reference plane from which the incisor inclination may be measured. The reference planes that may be used are the maxillary plane, Frankfort Horizontal plane and the SN plane. As these reference planes are all subject to biological variability, incisor inclinations measured in this way should be interpreted with caution; ideally the incisor inclination should be determined using more than one reference plane, and the orientation of the respective reference plane to the craniofacial skeleton must also be determined to be within normal limits.

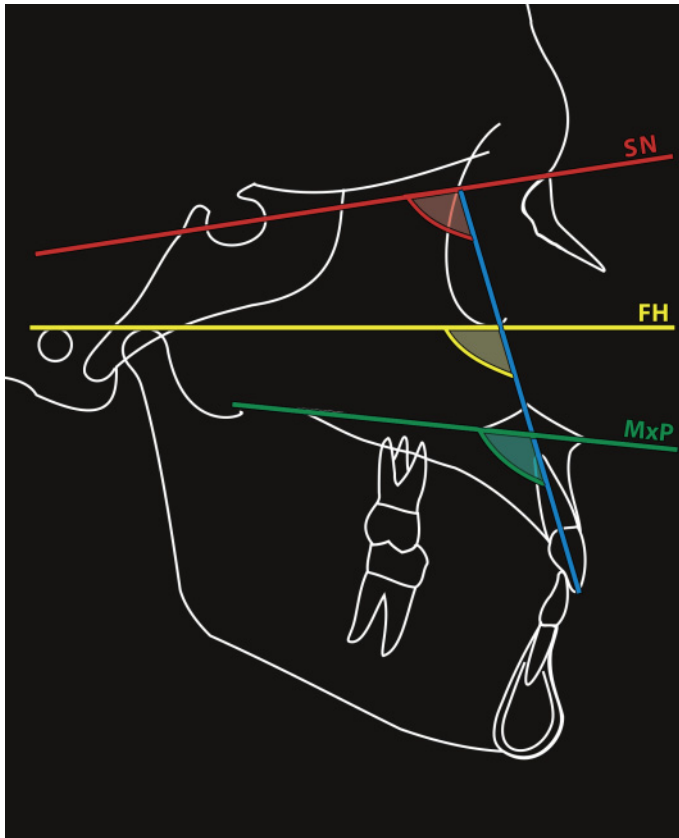


Figure 7.33 Maxillary incisor inclination may be evaluated in relation to the maxillary plane (MxP), the Frankfort Horizontal (FH) plane or the anterior cranial base (SN) plane.

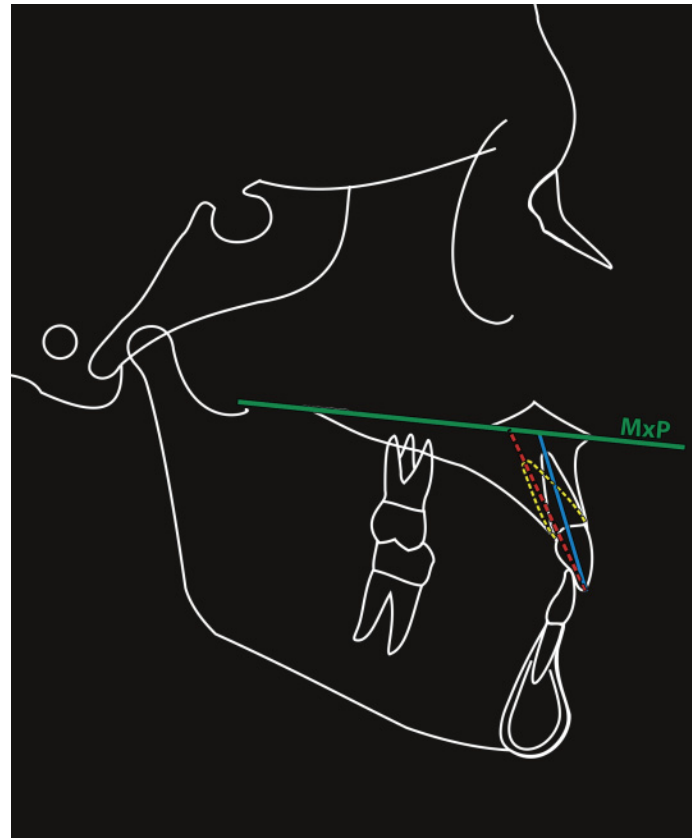


Figure 7.34 An unusually acute maxillary incisor crown-root angle may lead to an incorrect overestimation of the maxillary incisor inclination.

- Maxillary incisor to maxillary plane inclination (MxI-MxP)** (Figure 7.33): This is perhaps the most commonly employed value to determine maxillary incisor inclination. The result must be interpreted with caution as it will depend on three separate factors:
 - Inclination of the maxillary incisors:** Values greater or lesser than the normal range demonstrate proclination or retroclination of the maxillary incisors.
 - Eastman Standard: $109^\circ \pm 6^\circ$
 - Riolo et al. (USA, 1974):³⁴ male $112^\circ \pm 6^\circ$; female $111^\circ \pm 6^\circ$
 - Bhatia and Leighton (UK, 1993):²⁷ male $112^\circ \pm 9^\circ$; female $109^\circ \pm 9^\circ$.
- Crown-root angle** (Figure 7.34): If there is an unusually acute maxillary incisor crown-root angle, this may lead to an incorrect evaluation of the maxillary incisor inclination.
- Inclination of the maxillary plane** (Figure 7.35): The inclination of the maxillary plane (sagittal rotation around the transverse axis) will affect the MxI-MxP plane inclination. For example, if the posterior nasal spine is canted upward posteriorly, the value of MxI-MxP will be increased.
- Maxillary incisor to sella-nasion (SN) plane inclination (MxI-SN)** (Figure 7.33): The long axis of the maxillary incisor is extended to intersect the SN plane and the posterior angle is measured. Again, the maxillary incisor crown-root angle and the orientation of the SN plane must be taken into account
 - Riolo et al. (USA, 1974):³⁴ male $105^\circ \pm 6^\circ$; female $103^\circ \pm 7^\circ$
 - Bishara (USA, 1981):³⁵ $102^\circ \pm 6^\circ$
 - Bhatia and Leighton (UK, 1993):²⁷ male $105^\circ \pm 9^\circ$; female $101^\circ \pm 9^\circ$.

Note

The Eastman Standards are standard cephalometric values that have been used for many years at the Eastman Dental Hospital in London, based on the 'normative data' from a variety of UK and other European studies.

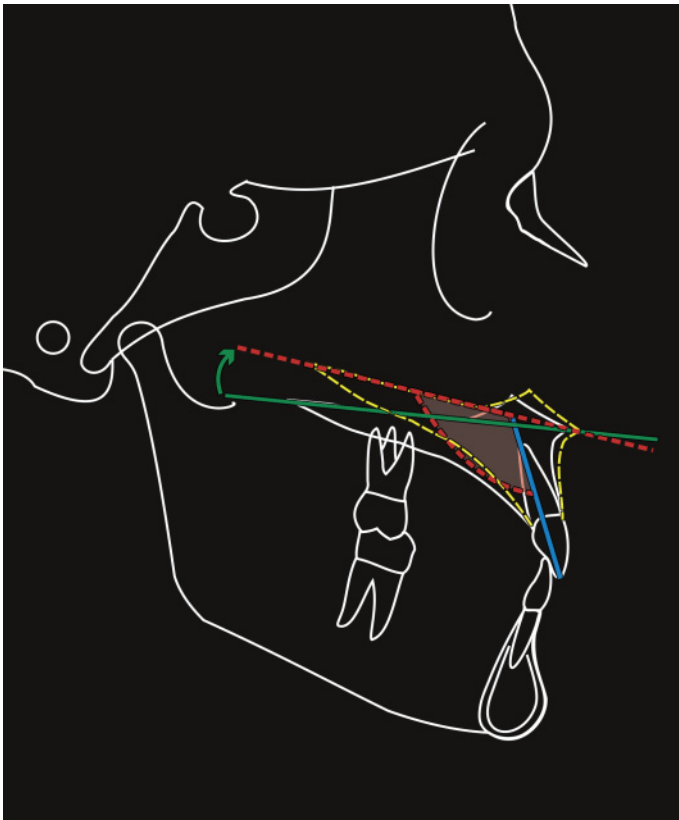


Figure 7.35 The inclination of the maxillary incisor to the maxillary plane will depend on the inclination of the maxillary plane.

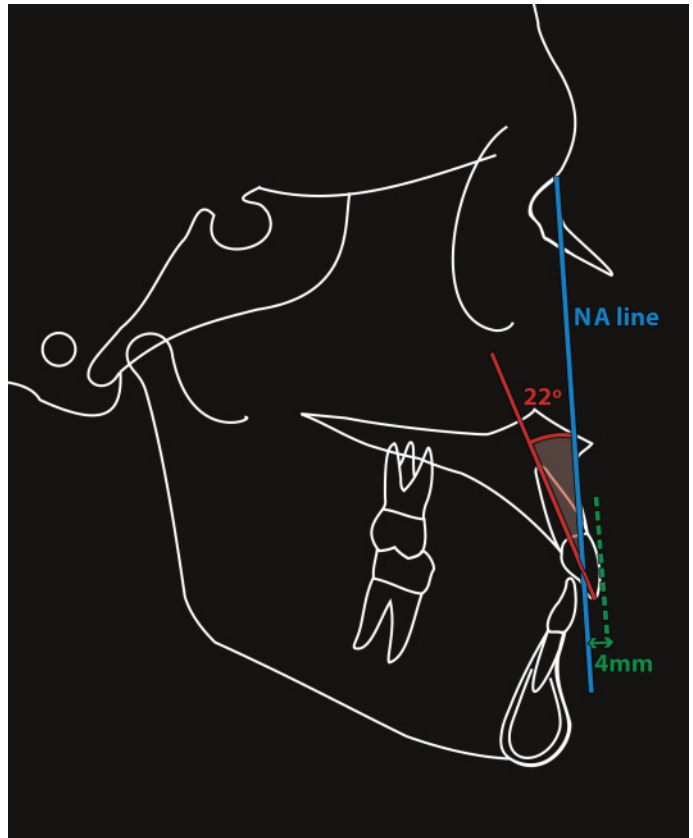


Figure 7.36 According to Steiner, the most anterior point of the maxillary incisors should be 4mm ahead of the NA line, and the maxillary incisor axial inclination is 22° to NA line.

- **Maxillary incisor to Frankfort Horizontal plane** (Figure 7.33): The long axis of the maxillary incisor is extended to intersect the Frankfort plane and the posterior angle is measured. Again, the maxillary incisor crown-root angle and the inclination of the Frankfort plane must be taken into account:
 - Riolo et al. (USA, 1974):³⁴ male $108^\circ \pm 8^\circ$; female $111^\circ \pm 6^\circ$
 - Bhatia and Leighton (UK, 1993):²⁷ male $114^\circ \pm 9^\circ$; female $112^\circ \pm 8^\circ$
 - Burstone (USA, 1978):¹³ male: $109^\circ \pm 9^\circ$; female $112^\circ \pm 7^\circ$; Burstone uses the constructed Frankfort Horizontal plane.
- **Maxillary incisor to NA line (Steiner)** (Figure 7.36): Steiner related the relative position and inclination of the maxillary incisor to the nasion-point A (NA) line:^{8,9}
 - The most anterior point of the maxillary incisors should be 4mm ahead of the NA line. This relates the sagittal position of the incisor to the maxilla. The sagittal position of the maxilla to the craniofacial complex must therefore be assessed using another analysis
 - Maxillary incisor axial inclination is 22° to NA line.

Sagittal position of the maxillary incisors

The sagittal position of the maxillary incisors to the maxilla may be assessed using Steiner's NA line described above (Figure 7.36).^{8,9} Important analyses to assess the sagittal position of the maxillary incisors to the craniofacial complex are:

- **Maxillary incisor to N-perpendicular (McNamara analysis)** (Figure 7.37): A vertical line is drawn through maxillary A-point, parallel to the N-perpendicular, and perpendicular to the Frankfort Horizontal (or ideally true horizontal) plane. The labial (facial) surface of the maxillary incisor should be 4–6 mm ahead of the line.²⁶
- **Maxillary incisor to A-Pog line (Downs analysis)** (Figure 7.38): The protrusion of the maxillary incisors may be measured as the distance between the incisal edge of the maxillary incisor to the point-A to pogonion (A-Pog) line.³⁶
 - Downs³⁶ gives value of: 2.7 ± 1.8 mm
 - Ricketts¹⁶ gives value of: 5.7 ± 3 mm
 - Reading is positive if the incisal edge is ahead of and negative if behind the A-Pog line
 - Bhatia and Leighton (UK, 1993):²⁷ male 5 ± 2.5 mm; female 4 ± 2.5 mm
 - Assuming normal Class I incisor relationship: 2–4 mm.

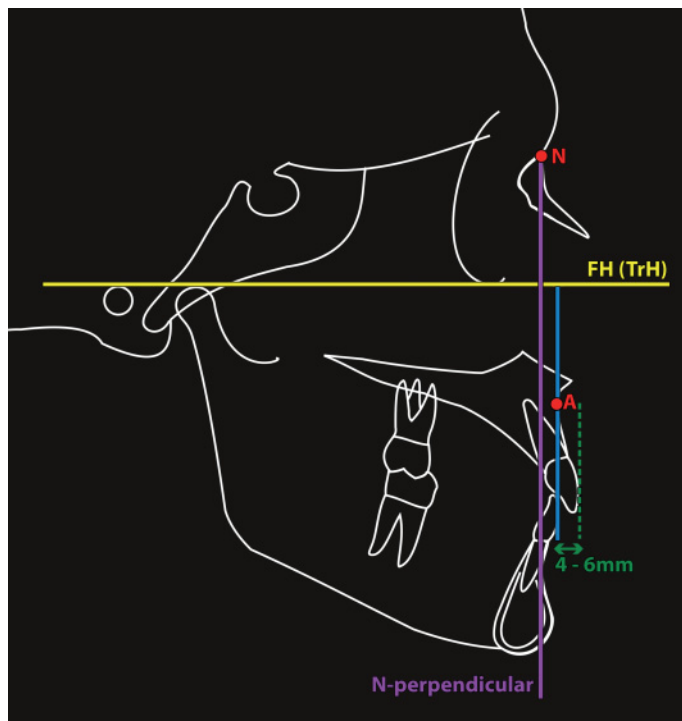


Figure 7.37 The labial (facial) surface of the maxillary incisor should be 4–6mm ahead of a line through maxillary A-point, perpendicular to the true horizontal (TrH) plane.

Note

Downs credited Ricketts with suggesting that the position of the mandibular incisors to the A-Pog line was important in the aesthetics of the lower face.³⁶ The A-Pog line was popularized by Williams (1969), which he termed the **diagnostic line**.¹⁴

Inclination of the mandibular incisors

- **Mandibular incisor to mandibular plane (MnI-MnP: $92^\circ \pm 5^\circ$)** (Figure 7.39): The average value and the range of variation given are only appropriate if the maxillary-mandibular planes angle (MMPA) and the skeletal pattern are within normal limits.
 - **Skeletal pattern:** Patients with acceptable facial soft tissue aesthetics may have an underlying Class II or Class III skeletal pattern. In such patients, *dentoalveolar compensation* will be a favourable feature permitting an acceptable dental occlusion despite the skeletal discrepancy. Therefore, the mandibular incisor inclination should always be interpreted with reference to the skeletal pattern.
 - **Maxillary-mandibular planes angle (MMPA or MM angle)** (Figure 7.39): If the MMPA is increased, there
- **Mandibular incisor to Frankfort Horizontal plane** (Figure 7.39): This angle relates the axial inclination of the mandibular incisors to the Frankfort Horizontal plane, which avoids any variation due to the inclination of the mandibular plane.
 - **Frankfort-mandibular incisor angle (FMIA):** Charles Tweed described the FMIA as part of the 'Tweed triangle'.³⁷ It is the inferior posterior angle formed by the intersection of the long axis of the mandibular central incisor and the Frankfort Horizontal plane. Normal values are 62–70°.
- **Mandibular incisor to NB line (Steiner)** (Figure 7.40): The axial inclination of the mandibular central incisor to the nasion-B-point (NB) line should be 25°. ^{8,9}

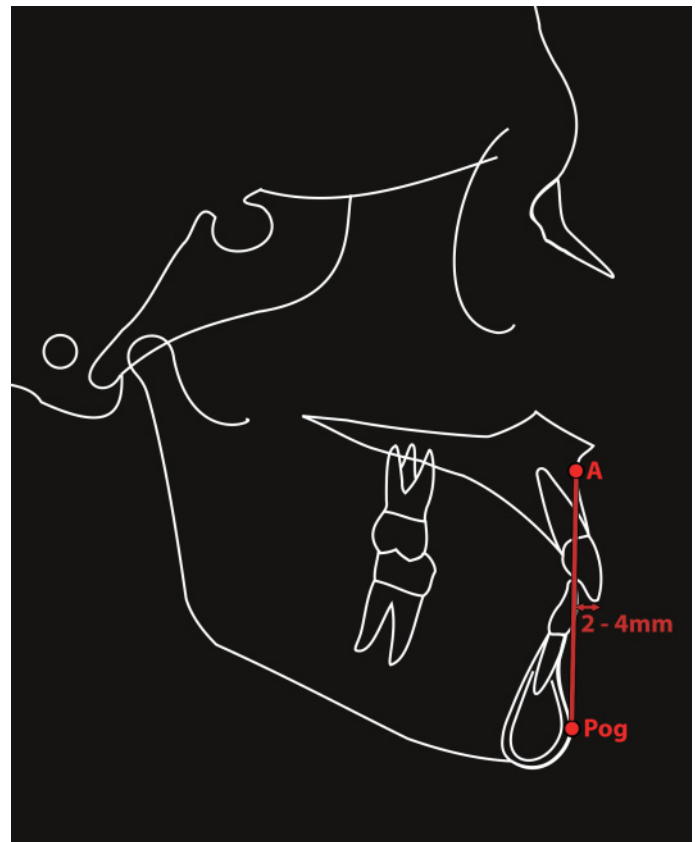


Figure 7.38 The protrusion of the maxillary incisors may be measured as the distance between the incisal edge of the maxillary incisor to the A-Pog line.

tends to be a compensatory retroclination of the mandibular incisors. Conversely, in 'low angle' patients, the mandibular incisors may be proclined. Therefore, there is an inverse relationship between the MMPA and the MnI-MnP. A useful check is that the MMPA + MnI-MnP should be equal to 120°. Hence, for every degree the MMPA exceeds its average value, the expected value of the mandibular incisor inclination should be reduced by 1°, and vice versa.

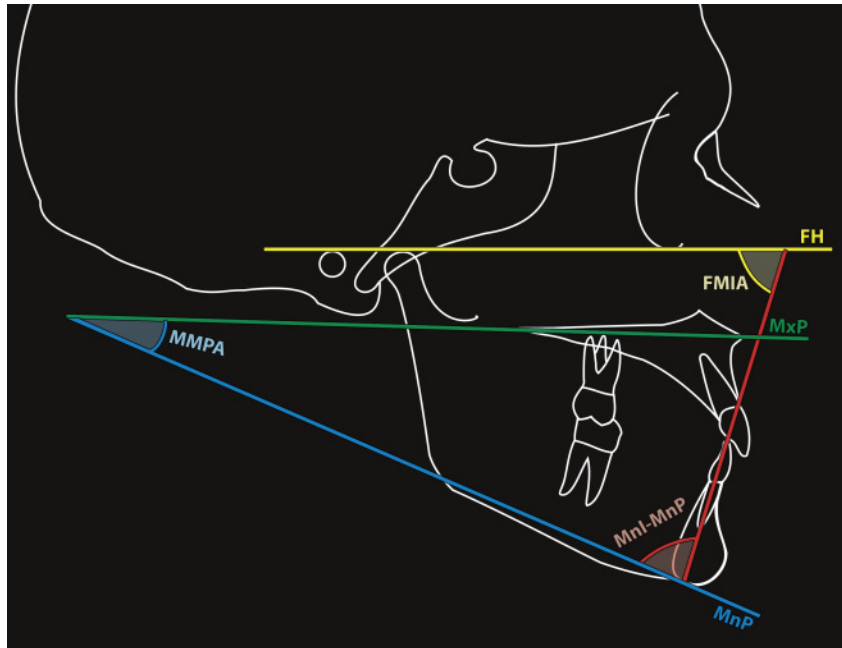


Figure 7.39 The axial inclination of the mandibular incisors (MnI) may be evaluated in relation to the mandibular plane (MnP) or to the Frankfort Horizontal (FH) plane, forming the Frankfort-mandibular incisor angle (FMIA) of Tweed. MxP, maxillary plane; MMPA, maxillary-mandibular planes angle.

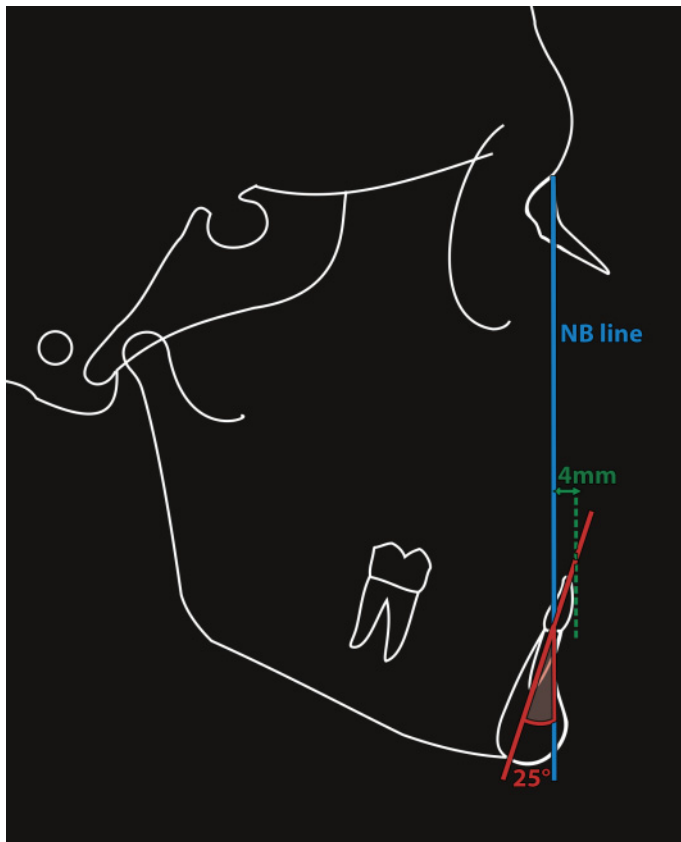


Figure 7.40 According to Steiner, the most labial portion of the crown of the mandibular central incisor should be located 4mm ahead of the NB (nasion-point B) line; the axial inclination of the mandibular central incisor to the NB line should be 25°.

Sagittal position of the mandibular incisors

- **Mandibular incisor to NB line (Steiner)** (Figure 7.40): The most labial portion of the crown of the mandibular central incisor should be located 4mm ahead of the NB line.^{8,9}
- **Mandibular incisor to A-Pog line (Downs)** (Figure 7.41): This is the perpendicular distance of the mandibular central incisor edge to the A-Pog line.³⁶ It represents the degree of mandibular incisor protrusion in relation to the lower face. In individuals with good dentofacial aesthetics and good dental occlusions, the *mandibular incisor edge lies on or close to the A-Pog line*.
 - Bhatia & Leighton (UK, 1993):²⁷ 1 ± 2.5 mm (Female: 1 ± 2 mm).

It is important to bear in mind that the orientation of the A-Pog line is influenced by the sagittal position of maxillary A-point and the prominence of the chin.

- **Mandibular incisor edge to maxillary incisor centroid relationship (Houston)** (Figure 7.42): This is measured as the distance between the perpendicular projections of the mandibular incisor edge and the centroid of the maxillary incisor root onto the maxillary plane.³⁸ The mandibular incisor edge projection should be coincident with or up to 2mm ahead of the centroid projection. This relationship is closely associated with incisor overbite depth in that the further posterior to the centroid the mandibular incisor edge lies, the deeper the overbite is likely to be, unless there is an incomplete overbite. Correction of this relationship with orthodontic treatment is an important factor in overbite stability.

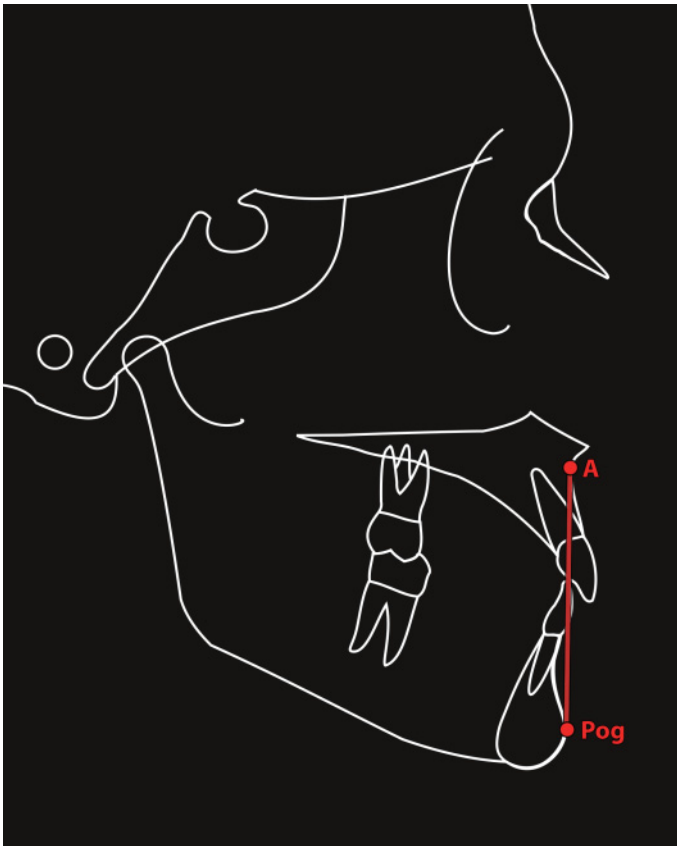


Figure 7.41 In individuals with good dentofacial aesthetics and good dental occlusions, the mandibular incisor edge lies on or close to the A-Pog line.

Inclination of maxillary to mandibular incisors

The interincisal angle ($133^\circ \pm 10^\circ$): This was described by William Downs,³⁶ and is the posterior angle formed by the intersection of the long axes of the maxillary and mandibular central incisors (Figure 7.43). When there is incisor contact, the interincisal angle is associated with the depth of incisor overbite, i.e. the incisor teeth tend to erupt past one another if the interincisal angle is increased, resulting in a deep overbite.

Note

A simple geometrical relationship exists in that the sum of the maxillary-mandibular planes angle, maxillary incisor to maxillary plane inclination (MxI-Mx), mandibular incisor to mandibular plane inclination (MnI-Mn) and interincisal angle (MxI-MnI) should be 360° .

Vertical skeletal relationships

There is no single cephalometric variable that reliably distinguishes normal from vertically abnormal individuals. In order to accurately evaluate vertical proportions, it is necessary to analyse both **linear** anterior and posterior vertical dimensions (compared to age-, sex- and ethnicity-specific normative data, and as proportional relationships) and **angular** measurements comparing posterior and anterior vertical dimensions.

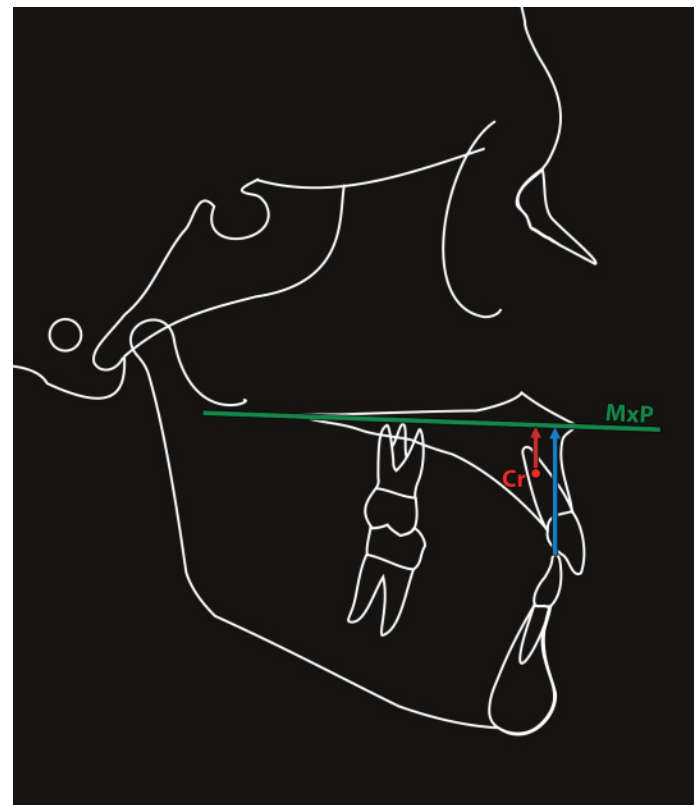


Figure 7.42 The edge-centroid relationship: the mandibular incisor edge projection should be coincident with or up to 2 mm ahead of the centroid (Cr) projection onto the maxillary plane (MxP).

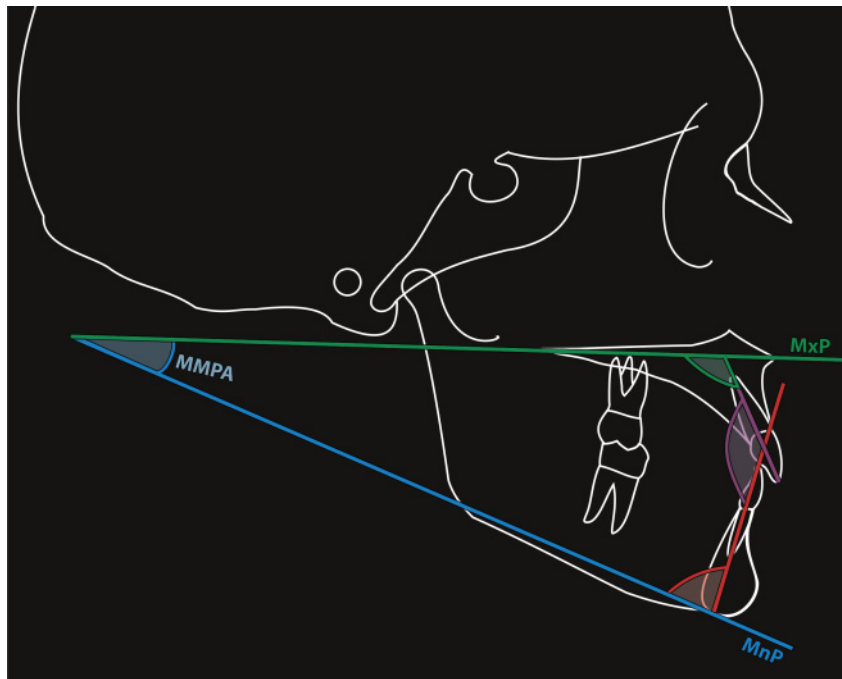


Figure 7.43 The interincisal angle is the posterior angle formed by the intersection of the long axes of the maxillary and mandibular central incisors; the sum of the maxillary-mandibular planes angle (MMPA), maxillary incisor to maxillary plane (MxP) inclination, mandibular incisor to mandibular plane (MnP) inclination and interincisal angle should be 360°.

Convergence of horizontal facial planes (Sassouni analysis)

The orthodontist Viken Sassouni described the importance of analysing the relative orientation of the horizontal planes of the face.¹² He described four planes: the supraorbital plane, palatal plane, occlusal plane and mandibular plane. Sassouni explained that the most frequent tendency is for the planes to converge posteriorly towards a common centre, which he termed **centre 'O'**. This centre would be located as the centre of an area of 15 mm diameter, within which pass the planes. If any one plane is out of convergence to an extent that it passes outside this area, that plane and its associated structure is vertically out of proportion. A slightly modified version of this analysis may be employed, utilizing the following five horizontal facial planes (Figure 7.44A):

- The anterior cranial base (SN) plane.
- The true horizontal plane (or Frankfort Horizontal plane).
- Maxillary (palatal) plane.
- Occlusal plane.
- Mandibular plane.

In a well-proportioned face, these horizontal facial planes should converge symmetrically toward an approximate *area of intersection located near the occiput* (back of the skull). If any part of the face is vertically disproportionate, its associated plane will not converge with the others. Examination of the relationship among these horizontal planes reveals several distinct patterns:

- **Sagittal position of the area of convergence:** If the area of convergence of the horizontal facial planes is positioned well behind the occiput, the planes will be nearly parallel (Figure 7.44B). This skeletal pattern is associated with similar anterior and posterior facial heights, and correlates with a deep bite tendency, which Sassouni termed a 'skeletal deep bite', i.e. an increased incisor overbite aetiologically related to parallelism of the horizontal skeletal planes. If the area of convergence of the horizontal facial planes is positioned in front of the occiput, towards the face, the planes will diverge anteriorly (Figure 7.44C). This skeletal pattern is associated with markedly different anterior and posterior facial heights, and correlates with an anterior open bite tendency, which Sassouni termed a 'skeletal open bite', i.e. an anterior open bite aetiologically related to divergence of the horizontal skeletal planes.
- **Sagittal jaw rotation:** The direction and extent of sagittal rotation (around the transverse axis) of the maxilla, mandible or maxillomandibular complex may be gleaned by the inclination of a maxillary and/or mandibular plane that deviates from the area of intersection of the other planes. For example, patients with posterior vertical maxillary excess may have a maxilla that is canted down posteriorly.

Anterior and posterior face height

With a lateral cephalometric radiograph taken in NHP, the true vertical plane may be recorded on the radiograph by means of a

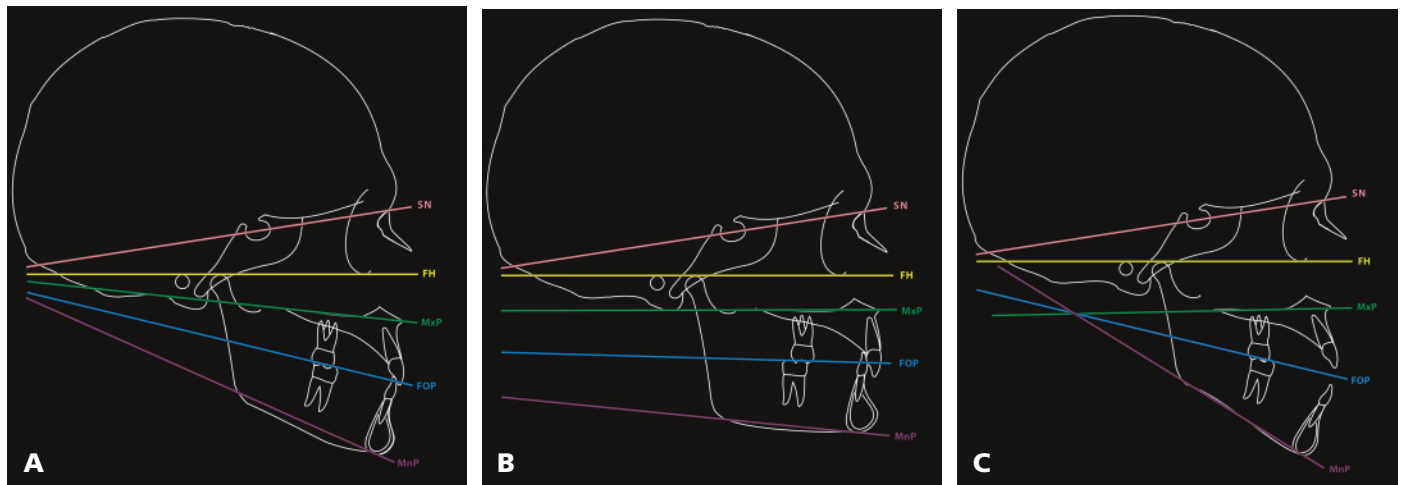


Figure 7.44 (A) According to the Sassouni analysis, in a well-proportioned face, the horizontal facial planes should converge symmetrically toward an approximate area of intersection located near the occiput. If any part of the face is vertically disproportionate, its associated plane will not converge with the others. (B) If the area of convergence of the horizontal facial planes is positioned well behind the occiput, the planes will be nearly parallel; this skeletal pattern is associated with similar anterior and posterior facial heights, and correlates with a deep overbite tendency, termed a 'skeletal deep bite'. (C) If the area of convergence of the horizontal facial planes is positioned in front of the occiput, towards the face, the planes will diverge anteriorly; this skeletal pattern is associated with markedly different anterior and posterior facial heights, and correlates with an anterior open bite tendency, termed a 'skeletal open bite'. MxP, maxillary plane; MnP, mandibular plane; FOP, functional occlusal plane; FH, Frankfort Horizontal plane; SN, sella-nasion plane.

plumb line. A number of vertical lines may be drawn parallel to the true vertical from a variety of points, such as nasion and sella. True horizontal planes may then be drawn perpendicular to the true vertical, through a variety of points, such as nasion, ANS and menton. The dentoskeletal structures may be related, ideally to the true vertical and horizontal planes, using angular and linear measurements. These measurements may be compared with population norms and used to analyse a range of proportional relationships.

- **Anterior face height ratio (proportional relationship of lower to middle anterior face height)** (Figure 7.45): Horizontal lines are projected from N, ANS and Me onto the true vertical. The middle anterior face height (MAFH) is measured from the projection of N to that of ANS. The lower anterior face height (LAFH) is measured from the projection of ANS to that of Me. The proportional relationship of MAFH:LAFH is approximately 45:55%. This proportional relationship is more important than any absolute measurements.

Note

The facial soft tissue proportion of middle to lower anterior face height measured clinically is 50:50. The reason that the skeletal proportion is not 50:50 when measured cephalometrically is that the uppermost point is nasion. If hard tissue glabella (on the frontal bone, horizontally in same position as soft tissue glabella) was used instead of nasion, the proportion would be 50:50.

- **Relationship of anterior to posterior face height:**

- **Facial Height Index (FHI; proportional relationship of anterior to posterior lower face height)** (Figure 7.46): The lower posterior face height (LPFH) is measured from articulare, tangent to the ascending mandibular ramus, to the mandibular plane. This may more accurately be referred to as the posterior ramus height, excluding the condyle. The lower anterior face height (LAFH) is measured from the maxillary plane to menton. The FHI is the ratio of LAFH to LPFH, and should be from 0.65–0.75.³⁹ Hence, if the lower posterior facial height is less than 65% or more than 75% of the lower anterior face height, there is likely to be a vertical skeletal discrepancy.

Note

The FHI must be analysed in conjunction with the anterior face height ratio. For example, if the anterior face height ratio (MAFH:LAFH) is correct, but the FHI is not, then the discrepancy lies in the LPFH, i.e. there is a reduced vertical ramus height.

- **Angular relationship of anterior to posterior face height:** The maxillary-mandibular planes angle ($27^\circ \pm 5^\circ$) is largely determined by the ratio of anterior and posterior intermaxillary heights. It is formed by the intersection of the maxillary plane (ANS-PNS) and the

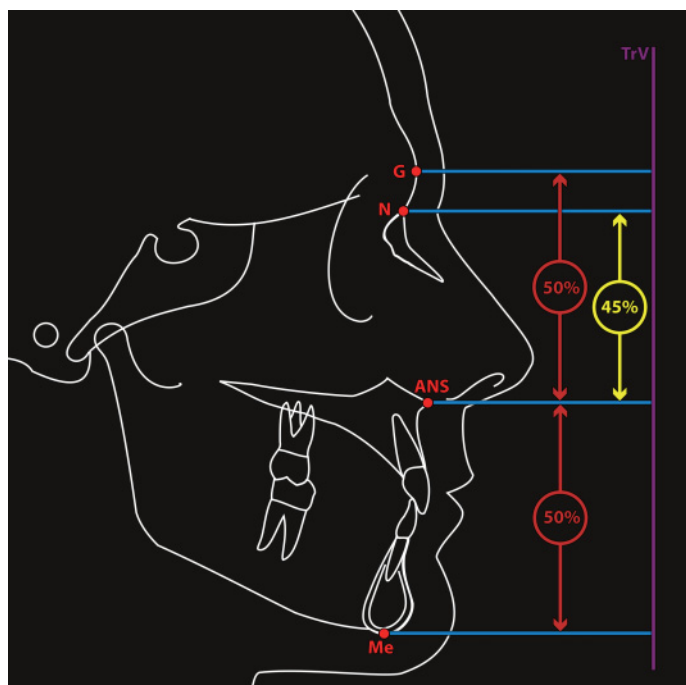


Figure 7.45 Anterior face height ratios (proportional relationship of lower to middle anterior face height). TrV, true vertical plane.

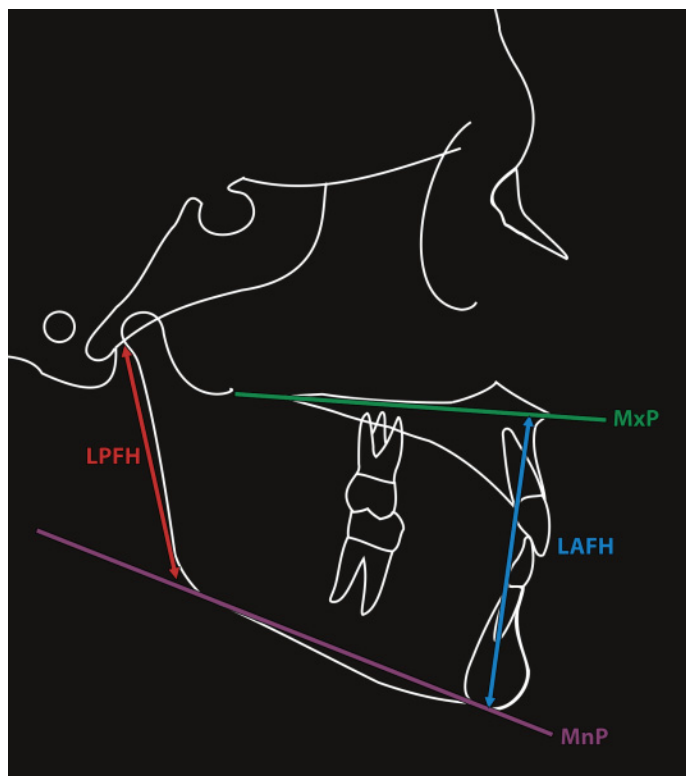


Figure 7.46 Facial Height Index (FHI: Proportional relationship of anterior [LAFH] to posterior [LPFH] lower face height) is the ratio of LAFH to LPFH, and should be from 0.65–0.75. If the lower posterior face height is less than 65% or more than 75% of the lower anterior face height, there is likely to be a vertical skeletal discrepancy. MxP, maxillary plane; MnP, mandibular plane.

mandibular plane (Go-Gn). Steiner assessed the steepness of the mandibular plane in relation to the SN plane (average 32°).⁸ Downs described the mandibular plane angle as the angle formed by the intersection of the Frankfort Horizontal plane and the mandibular plane

($22^\circ \pm 3^\circ$).³⁶ This angle may be assessed both clinically and cephalometrically. These variables must be assessed with an independent estimate of the lower anterior facial height, such as the anterior face height ratio (MAFH:LAFH).

Linear cephalometric measurements and normative values

See Table 7.9 and Figure 7.47.

Table 7.9 Normative linear vertical cephalometric measurements (numbers refer to Figure 7.47A,B)

No.	Parameter	Normative value (mm)			
		UK		US	
		Male	Female	Male	Female
1	Anterior face height (N-Me)	121 ± 7	112 ± 6	137 ± 8	123 ± 5
2	Midface height (N-ANS)	54 ± 2	51 ± 2	60 ± 4	56 ± 2
3	Midface height (N perpendicular to maxillary plane)	53 ± 2	50 ± 3	Not provided	Not provided
4	Lower face height (ANS-Me)	68 ± 6	63 ± 5	80 ± 6	69 ± 5
5	Lower face height (Me perpendicular to maxillary plane)	67 ± 6	61 ± 5	76 ± 6	67 ± 4
6	Sella-point A	86 ± 4	78 ± 3	99 ± 5	91 ± 6
7	Sella-gnathion (S-Gn)	129 ± 5	117 ± 4	144 ± 7	131 ± 5
8	Sella-PNS	50 ± 2	45 ± 2	56 ± 4	51 ± 3
9	Posterior face height (S-Go)	80 ± 4	72 ± 4	88 ± 6	79 ± 4
10	Lower posterior face height (Ar-Go)	49 ± 4	44 ± 4	54 ± 4	50 ± 4

UK data from Bhatia and Leighton;²⁷ US data from Riolo et al.³⁴

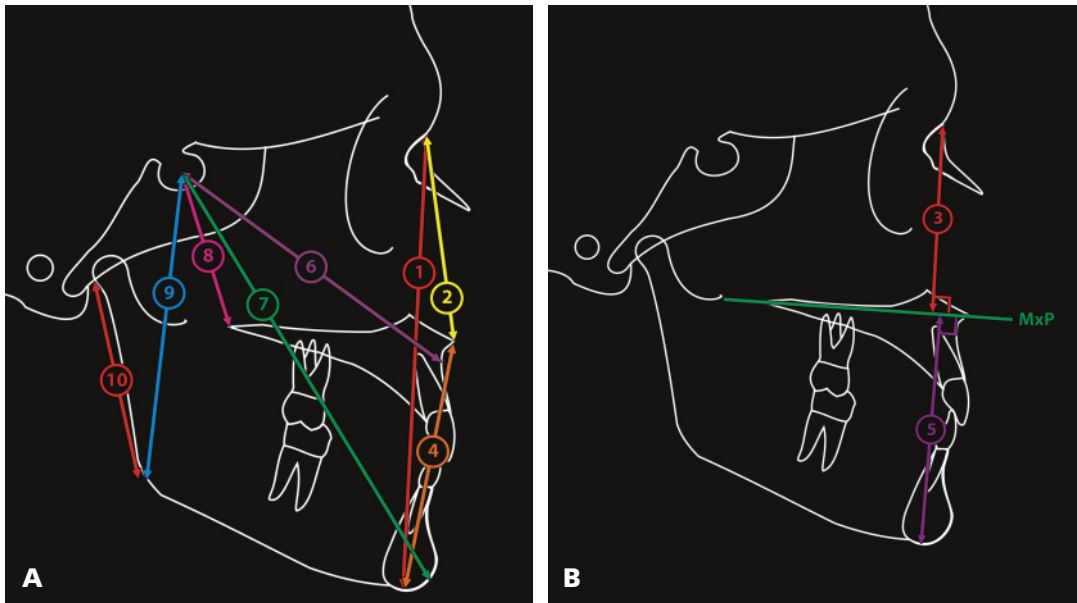


Figure 7.47A,B Linear vertical cephalometric measurements (numbers refer to normative values in Table 7.9). MxP, maxillary plane.

Angular cephalometric measurements and normative values

See Table 7.10 and Figure 7.48A,B.

Table 7.10 Normative angular vertical cephalometric relationships (numbers refer to Figure 7.48A,B)

No.	Angular relationship	Normative value (degrees)			
		UK		US	
		Male	Female	Male	Female
1	N-S-Gn	66 ± 5	68 ± 4	67 ± 4	66 ± 4
2	SN to Frankfort plane (Po-Or)	10 ± 3	11 ± 3	3 ± 4	5 ± 3
3	SN to maxillary plane (ANS-PNS)	6 ± 2	7 ± 3	7 ± 3	8 ± 2
4	SN to functional occlusal plane	15 ± 6	19 ± 3	14 ± 4	15 ± 3
5	SN to mandibular plane (Go-Me)	32 ± 7	34 ± 6	33 ± 5	31 ± 3
6	SN to posterior ramus plane (Ar-Go)	89 ± 6	89 ± 4	89 ± 5	89 ± 4
7	Frankfort- mandibular planes angle (FMPA)	22 ± 6	23 ± 5	29 ± 5	26 ± 3
8	Maxillary-mandibular planes angle (MMPA)	26 ± 7	26 ± 5	26 ± 5	23 ± 4

UK data from Bhatia and Leighton;²⁷ US data from Riolo et al.³⁴

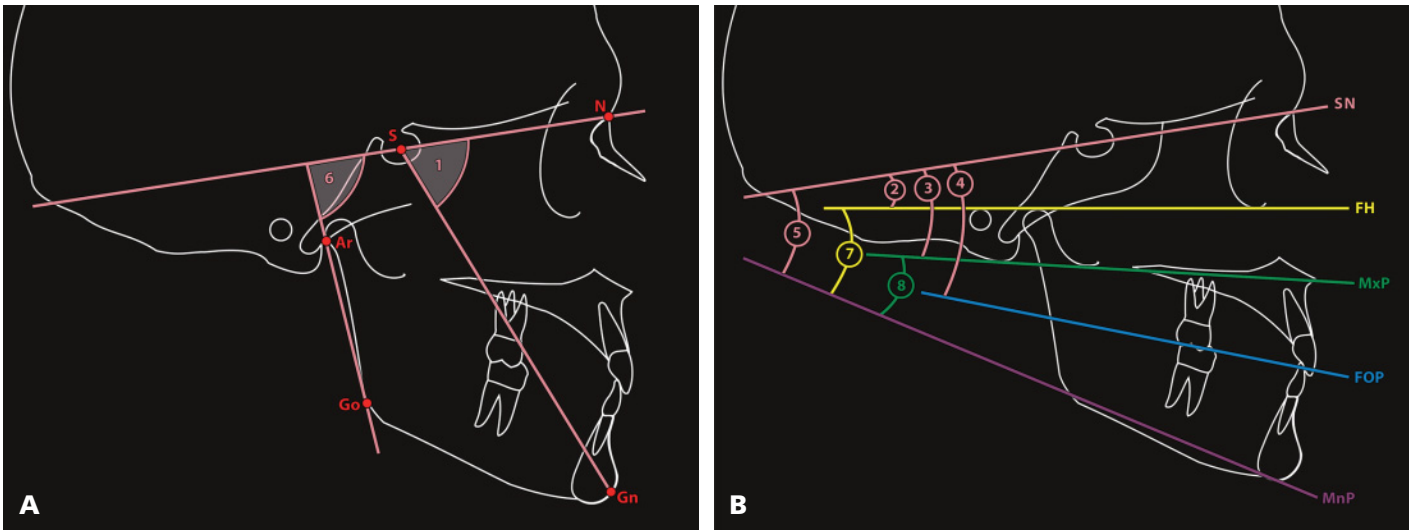


Figure 7.48A,B Angular vertical cephalometric relationships (numbers refer to normative values in Table 7.10). MxP, maxillary plane; MnP, mandibular plane; FOP, functional occlusal plane; SN, sella-nasion plane.

Note

Comparison of normative cephalometric data from the UK and US (Tables 7.9 and 7.10) demonstrates significant differences in the linear measurements but considerable similarity in

angular relationships. This demonstrates a difference in craniofacial size but similarity in shape between the two populations.

Vertical dentoalveolar relationships

In order to evaluate the vertical position of the teeth relative to their respective skeletal base, it is necessary to assess:

- The inclination of the occlusal plane.
- The distance of the maxillary incisors and posterior maxillary dentition to the maxillary plane.
- The distance of the mandibular incisors and posterior mandibular dentition to the mandibular plane.

Inclination of the occlusal plane

This should be harmonious with the other skeletal planes, as described in the Sassouni analysis. Traditionally, the occlusal plane is drawn from first molar to incisor overlap. Although the occlusal plane along the line of posterior occlusion tends to be straight, it is subject to considerable variation anteriorly depending on the incisor relationship and curve of Spee. This may also be evident by assessing the maxillary and mandibular occlusal planes:

- The **maxillary occlusal plane** is a line joining the cusp tips of the maxillary first permanent molars to the incisal edges of the maxillary central incisors.
- The **mandibular occlusal plane** is a line joining the cusp tips of the mandibular first permanent molars to the incisal edges of the mandibular central incisors.

A more accurate assessment of dental vertical relationships may be obtained by using the functional occlusal plane, a line drawn through the occlusal surfaces of the maxillary and mandibular first permanent molars and premolars, i.e. along the line of dental occlusion.

Anterior maxillary dental height (1) (Figure 7.49)

Anterior maxillary dental height is measured from the maxillary incisor tip to the maxillary plane.

- Male: $28 \pm 3 \text{ mm}^{27}$ (US: $33 \pm 3 \text{ mm}$).³⁴
- Female: $27 \pm 3 \text{ mm}^{27}$ (US: $30 \pm 3 \text{ mm}$).³⁴

An increase in this dimension may be indicative of excessive eruption of the maxillary incisors, such as in Class II division 2 malocclusion, or anterior vertical maxillary excess. A decrease in this dimension may occur in patients with an anterior open bite of soft tissue aetiology or those with prolonged digit sucking habits, where the anterior vertical incisor eruption has been impeded.

Posterior maxillary dental height (2) (Figure 7.49)

Posterior maxillary dental height is measured from the mesiobuccal cusp tip of the maxillary first molar to the maxillary plane.

- Male: $27 \pm 3 \text{ mm}^{27}$ (US: $28 \pm 3 \text{ mm}$).³⁴
- Female: $24 \pm 3 \text{ mm}^{27}$ (US: $25 \pm 2 \text{ mm}$).³⁴

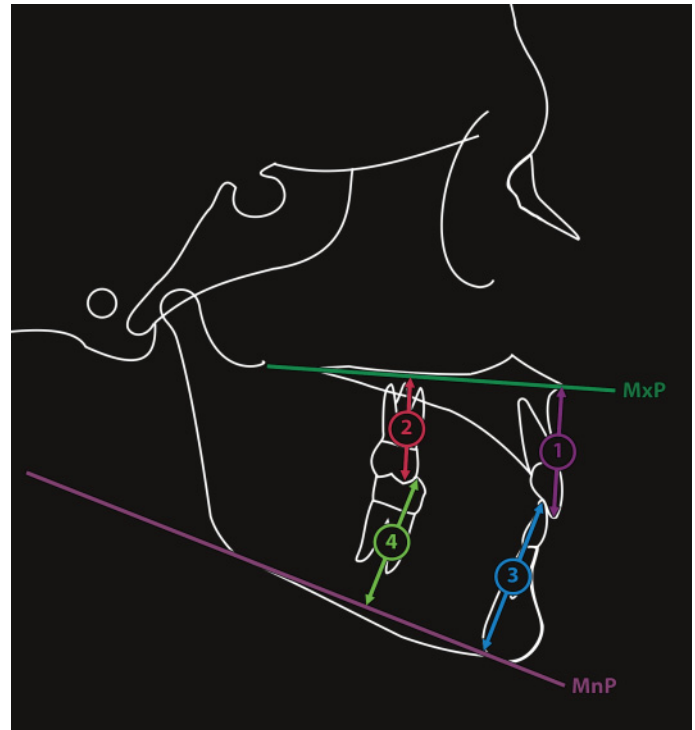


Figure 7.49 1: Anterior maxillary dental height; 2: Posterior maxillary dental height; 3: Anterior mandibular dental height; 4: Posterior mandibular dental height. MxP, maxillary plane; MnP, mandibular plane.

An increase in this dimension may be due to posterior vertical maxillary excess.

Note

In addition, the roots of the maxillary molars should be at, or no more than 3 mm inferior to the height of the palatal vault.

Anterior mandibular dental height (3) (Figure 7.49)

Anterior mandibular dental height is measured from the mandibular incisor tip to the inferior border of the mandible.

- Male: $40 \pm 3 \text{ mm}^{27}$ (US: $49 \pm 3 \text{ mm}$).³⁴
- Female: $38 \pm 3 \text{ mm}^{27}$ (US: $42 \pm 3 \text{ mm}$).³⁴

An increase in this dimension may be indicative of excessive eruption of the mandibular incisor teeth and/or increased vertical chin height. A decrease in this dimension may be due to impeded eruption of the mandibular incisor teeth or reduced vertical chin height.

Posterior mandibular dental height (4) (Figure 7.49)

Posterior mandibular dental height is measured from the mesiobuccal cusp tip of the mandibular first molar to the mandibular plane:

- Male: $34 \pm 3 \text{ mm}$ ²⁷ (US: $38 \pm 3 \text{ mm}$).³⁴
- Female: $33 \pm 3 \text{ mm}$ ²⁷ (US: $33 \pm 3 \text{ mm}$).³⁴

Transverse skeletal relationships

When evaluating the transverse (width) dimensions of the face, much of the most valuable diagnostic information is obtained from the clinical frontal facial analysis. Individuals presenting with significant facial asymmetry will require further assessment of the underlying dentoskeletal structures, using the PA cephalometric radiograph and, where necessary, three-dimensional imaging. Comprehensive evaluation of the transverse dimension, including analysis of the PA cephalometric radiograph is described in Chapter 10.

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SECTION 2 Facial Aesthetic Analysis: Facial Type, Proportions and Symmetry

Introduction to Section 2

‘The whole art of medicine is in observation ... but to educate the eye to see, the ear to hear and the finger to feel takes time ...’¹

There is no more difficult art to acquire than the art of observation...’²

Sir William Osler (1849–1919), Father of Modern Medicine

‘Rules’ versus ‘guidelines’ in facial aesthetic evaluation

‘Rules are for the guidance of wise men and the blind obedience of fools.’

Attributed to Sir Douglas Bader (1910–82), Second World War legless fighter pilot and social reformer

There are no rules in facial aesthetic evaluation; all the analyses described serve as **guidelines** to aid the clinician in understanding the structural and morphological characteristics of the craniofacial complex of each patient. **Aesthetic guidelines** may be based on:

- Classical, Renaissance and neoclassical canons of proportion.
- Modern anthropometric and cephalometric data from population norms.
- The results of attractiveness perception studies.

To be able to recognize abnormal craniofacial morphology, the clinician must have a thorough knowledge of **normative standards of comparison**, which may be used as **frames of reference**. The trained clinician will use all the above data and *selected* parts of *relevant* analyses as **diagnostic guides**. Nevertheless, the diagnosing clinician must learn to apply the acquired information to each patient, i.e. the final analysis for each patient is *individualized*.

Clinical inspection – the ‘process’

‘You see, but you do not observe.’

The distinction is clear ... I have both seen and observed.’

Arthur Conan Doyle (1859–1930), ‘A scandal in Bohemia’, in *The Adventures of Sherlock Holmes* (1891)³

The term **clinical inspection** refers to the accurate, thorough and systematic observation of a patient with a trained eye. The purpose of clinical inspection is:

- **Observation:** To *extract the salient information* from thorough observation of the patient in repose and in animation; *superficial observation inevitably leads to incorrect diagnosis*.
- **Palpation:** *Manual palpation* of the craniofacial region, in order to help relate the surface anatomy to the deeper structures – a number of bony prominences and the thickness of the overlying soft tissues may be palpated.
- **Analysis of diagnostic records.**

In the management of facial deformities clinical diagnosis is essentially **descriptive diagnosis**, i.e. it requires the *ability to accurately describe the morphological features and structural relationships of the craniofacial complex*. This 'ability' requires a **trained eye**.

Clinical inspection – the 'education of the eye'

'It was invisible, buried in the mud.
I only saw it because I was looking for it.'

Arthur Conan Doyle (1859–1930), 'Silver blaze', in *The Adventures of Sherlock Holmes* (1891)³

Artists refer to *training in observation* as the **education of the eye**. Such ability may only be gained from keen observation and analysis of a large number of patients and their diagnostic records, until the clinician gains the ability to discern characteristics that are not necessarily obvious to the untrained eye.

Leonardo da Vinci termed this concept *saper vedere*, or 'knowing how to see'. A layperson will look at a beautiful building and may see that it is beautiful, but they will not necessarily be able to explain *why* it appears beautiful to them. They will not *see* the building in the same way as a professional architect. The architect will know what to look for, i.e. *saper vedere*.

Training in observation follows the same principles as training in any activity – there is no substitute for extensive practice. The clinician must become *obsessed with observation*. Effective clinical observation also requires a strong theoretical background; for only by being familiar with normal craniofacial anatomy and aesthetic principles will the clinician notice something as unusual. The human face is one integrated whole, yet consists of a myriad component parts. Training in observation is thereby the essential prerequisite to accurate clinical diagnosis.

'Everything has beauty, but not everybody sees it.'

Confucius (c. 551–479 BC), *Analects*⁴

The diagnostic process – clinical evaluation

'Only observation is the key to understanding.'⁵

Leonardo da Vinci (1452–1519)

The clinical evaluation of the craniofacial complex essentially consists of three consecutive stages (Figure S2.1):

- **Initial qualitative evaluation.**
- **Quantitative analysis.**
- **Subsequent qualitative evaluation.**

The initial qualitative evaluation involves observation of the patient and is required to acquire preliminary data, albeit

somewhat subjective. The quantitative analysis involves anthropometric and cephalometric data collection and analysis; it must be systematic, accurate and thorough. The subsequent qualitative evaluation involves observation of the patient in light of the previous findings; it must be *assiduous* and *reflective*. The clinician must synthesize the data from the initial qualitative evaluation and the quantitative analysis – the purpose is to see whether the results of the quantitative analysis corroborate the initial qualitative evaluation. If they do, the descriptive clinical diagnosis may be made; if they do not, the process must be started again in order to find out where the discrepancy has arisen.

Qualitative evaluation

'Painters ... move away from what they are painting and stand further back ... everything can be more correctly viewed.'

Leon Battista Alberti (1404–72), *De Pictura* ('On Painting', 1435)⁶

The **viewing position** of the patient and clinician and the **viewing distance** between the patient and the clinician are important considerations in the *initial* qualitative facial evaluation.

Viewing (observational) position

A practical viewing position is required for the initial qualitative facial evaluation. The patient must be examined in natural head position (NHP), and their head should be level with that of the clinician. Ideally the patient and clinician may stand facing one another. However, in situations where there is a significant height difference between the patient and clinician, they may be seated on adjustable seats with their heads level, taking care to maintain the patient's head in NHP.

Viewing (observational) distance

An *initial* viewing distance between the patient and the clinician of approximately **1 m** is recommended.

Quantitative evaluation and analysis

The quantitative evaluation involves thorough craniofacial anthropometric and cephalometric evaluation and the analysis of other diagnostic records where necessary. The purpose is to:

- **Obtain objective data** – i.e. collection of factual data that is *free from subjective opinion*, e.g. linear and angular craniofacial measurements.
- **Analyse the objective data** – i.e. proportional analysis, bilateral symmetry analysis and comparison of measurements to age-, sex- and ethnicity-specific normative values.

The clinical data collected from the qualitative and quantitative evaluation may be used to assess the following:

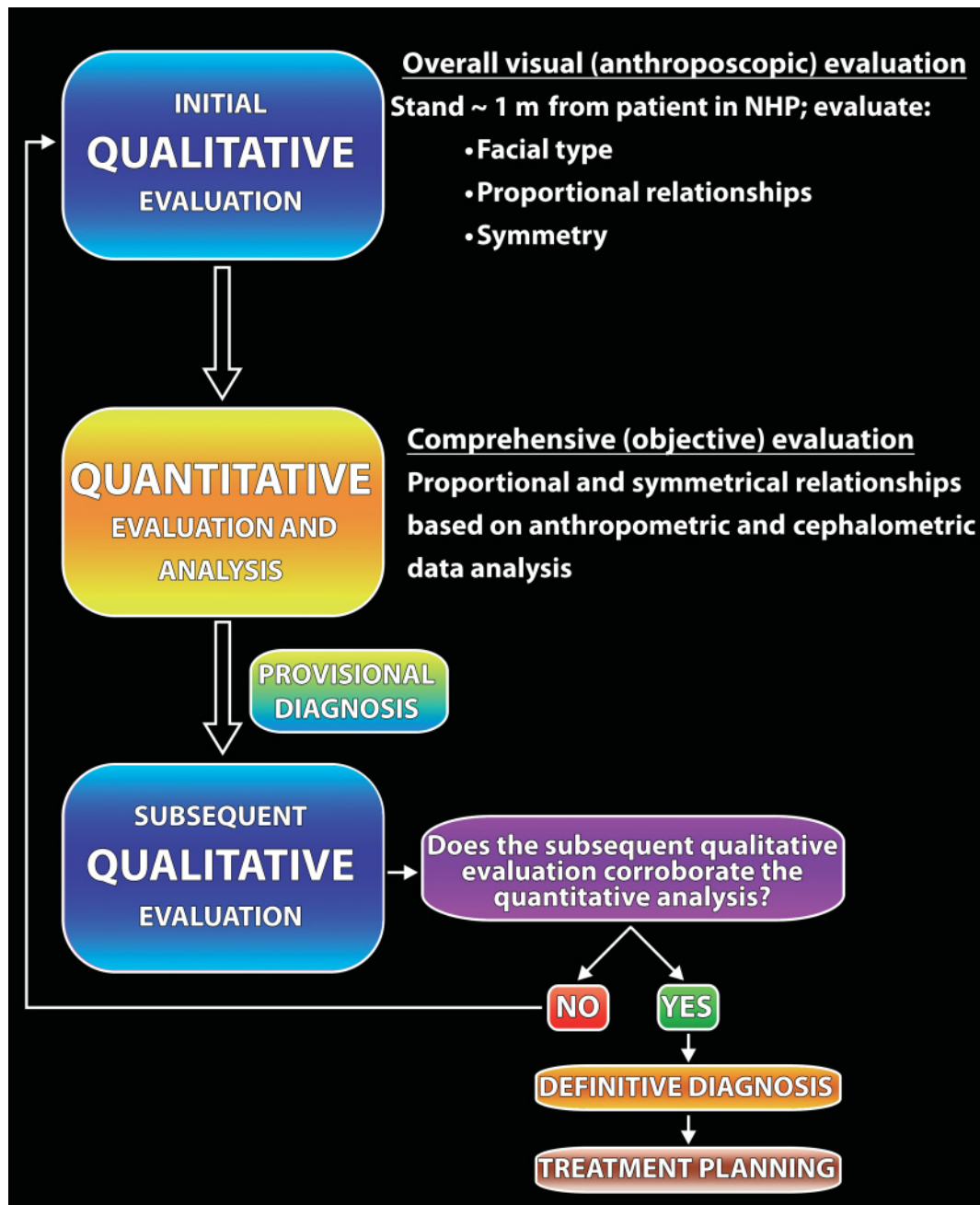


Figure S2.1 The diagnostic process in facial aesthetic evaluation.

1. **Define the normal:** Define which craniofacial structures are of normal size and morphology and in the 'correct' relative position.
2. **Define the abnormal:** Define which craniofacial structures are of abnormal size and/or morphology and in an 'incorrect' relative position.
3. **Relate the abnormal to the normal:** Identify which analysis may be used to relate the structures identified in the 'incorrect' relationship to those in the 'correct' relationship.
4. **Check findings:** Identify alternative analyses that may be used to check the craniofacial relationships.

Note

The diagnostic process: In the management of dentofacial and craniofacial deformities, **clinical diagnosis** is not a once-only event, but is a *continuing process*. The patient must be re-evaluated throughout treatment. This is particularly important in the management of patients requiring orthognathic surgery, as considerable facial changes occur during the presurgical orthodontic phase. In addition, changes due to growth, soft tissue maturation and subsequent ageing must all be taken into consideration.

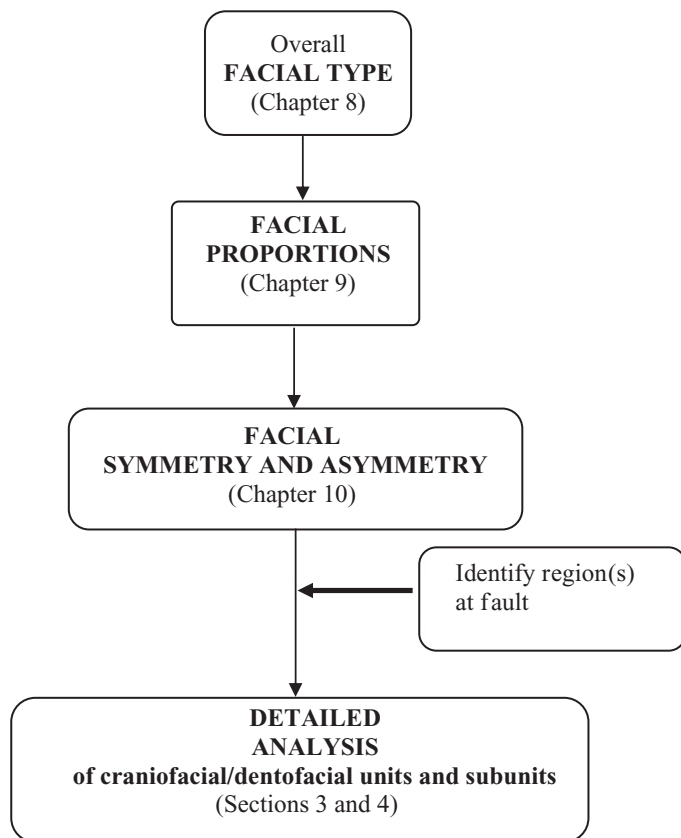


Figure S2.2 Clinical evaluation – the sequence.

Clinical evaluation – the sequence

Thorough clinical evaluation, required for accurate clinical diagnosis, should be **systematic**. A methodical approach to clinical evaluation permits *sequential progress through a number of successive stages* required to collect and analyse relevant data.

The following sections and their chapters should form an almost uninterrupted, *consecutive sequence* for clinical evaluation (Figure S2.2).

Section 2 describes the overall clinical evaluation of facial type, facial proportions and bilateral symmetry. Following these stages the clinician will have identified the facial regions ‘at fault’. Section 3 describes the detailed evaluation and analysis of the separate facial aesthetic units, using a ‘top-down’ approach (forehead to submental-neck region). Section 4 describes the clinical evaluation of the dental-occlusal complex and smile analysis.

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Chapter 8 Facial Type

Introduction

‘It is the common wonder of all men, how among so many millions of faces, there should be none alike.’

Sir Thomas Browne (1605–82), English physician and writer, *Religio Medici* (1643)¹

Individual variability is a fundamental principle in human biology. One of the most variable and distinguishable parts of the human body is the craniofacial complex.

The fictional conception of the ‘normal’

Clinicians will often compare a patient’s craniofacial measurements and proportions to the so-called population **norms** (normative values) or even to classical **ideals**. However, Simon (1926) stated:

‘all we ever find are variations; an exact, ideal normal does not exist, cannot exist. And this is our enigma; in theory we will never find the normal, in practice we forever feel its need and apply it constantly.’²

The use of population norms may be logically enhanced by evaluating **normal ranges of variability**. Therefore, clinicians must have a thorough understanding of the normal ranges of variability in every aspect of craniofacial form, depending on age, sex and ethnic variability.

Developmental disorders, as well as traumatic injuries and pathological conditions, may lead to **deformities** of the head and the face. Therefore, clinicians also need to have a thorough understanding of the normal anatomy and morphological range of variation of the craniofacial complex in both males and females

of different ages and ethnic groups, to act as guidelines when treatment planning the restoration of normal craniofacial proportions. Classifications that are useful for descriptive purposes include:

- **General craniofacial shape:** The overall shape of the head and face.
- **Anthropometric and cephalometric measurements:** Linear and angular craniofacial anthropometric and cephalometric measurements, compared with population norms, including means and ranges of variability.
- **Proportional relationships:** in the sagittal, vertical and transverse planes, based on:
 - Classical and/or Renaissance ‘ideals’
 - Anthropometric and cephalometric normative data from population samples
 - Attractiveness perception data based on contemporary patient population and/or layperson survey preferences.
- **Numerical proportion indices:** the relationship of two or more craniofacial anthropometric measurements.

Proportion indices

A **proportion index** provides a numerical expression of the proportionality of a region of the craniofacial complex. The use of proportion indices dates back through the history of craniometry, particularly in the late nineteenth century. Linear (chord) or surface (arc) distances of the skull were measured between a variety of defined craniofacial landmarks; with any two measurements, the smaller was expressed as a percentage of the larger in order to provide a proportion index value. These could be used to provide an indication of skull shape.

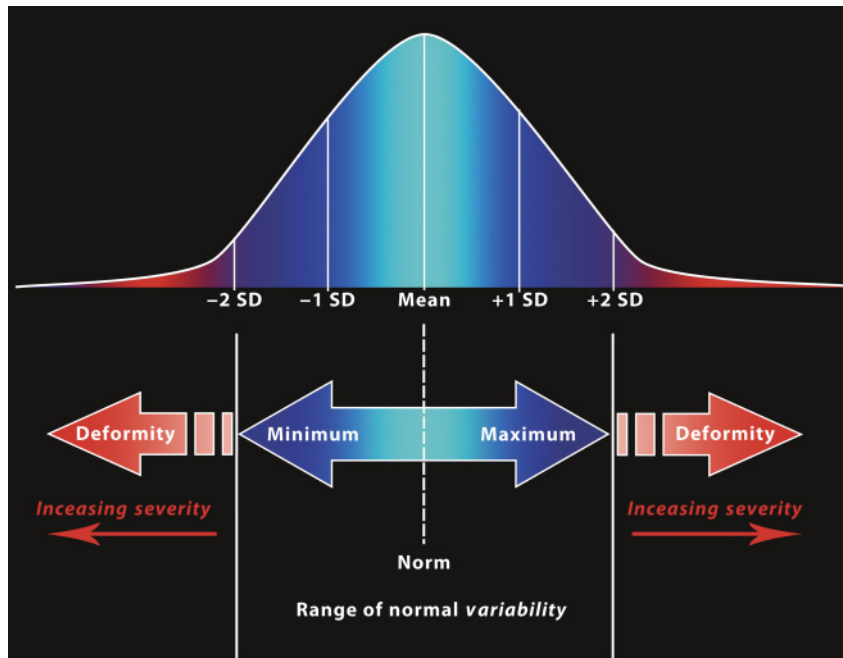


Figure 8.1 Determination of the normality or abnormality of any craniofacial measurement (or proportion index value) obtained from patients may be evaluated by comparison with the normative values obtained from a normal population sample. The normal range of measurements is provided by the mean ± 2 standard deviations (SD). The shape of the normal distribution curve shown is determined by the population standard deviation. Craniofacial parameters with small SDs have narrow, taller curves and those with large SDs have broader, flatter curves. Approximately 68% of all values fall within the range of ± 1 SD from the mean and 95% within the range of ± 2 SD from the mean. The normal range of variability for any craniofacial parameter is taken as being equal to the mean ± 2 SDs. Greater differences may be perceived as deformities of gradually increasing severity.

The leading researcher in the field of craniofacial anthropometry from the mid 1960s to the present day has been Leslie Farkas, from the University of Toronto. Farkas et al. collected a large quantity of highly relevant anthropometric data between 1968 and 1984, from 2564 individuals.³ These data were used to provide 166 individual facial ratios, presented as **proportion indices**. In the creation of an index, the smaller measurement is multiplied by 100 (numerator) and divided by the larger measurement (denominator). Thus, a **proportion index** involves two linear craniofacial anthropometric measurements, with the smaller being expressed as a percentage of the larger. *Proportion indices permit objective, quantitative assessment of facial morphology and proportions.*

Farkas³ identified two basic categories of proportion indices:

- **Areal (regional) indices** – composed of linear or angular measurements from only one anatomical area (e.g. nose).
- **Interareal (interregional) indices** – composed of linear or angular measurements from two or more anatomical regions (e.g. nose and face).

Each proportion index will have a **mean index value** and a range of variation for a given population group, based on age, sex and ethnicity. The standard deviation (SD) determines the normal range of variability of an index, from 2 SD below to 2 SD

above the mean. *Index values within this normal range are regarded as variations of normal proportions.*⁴ Measurements within ± 1 SD of the mean are regarded as *optimal*. The relationship between two measurements is disproportionate if the proportion index value is outside the normal range (Figure 8.1).⁴ For a number of facial parameters, single morphological measurements or proportion index values may have a large standard deviation and, therefore, wide normal ranges of variation; as such, only measurements or proportion index values which differ considerably from the mean of the population will be perceived as deformities. Conversely, other facial parameters may have very small normal ranges of variability, in which case even a small difference from the mean may be perceived as a deformity.

Note

Two abnormal measurements, which together make up a proportion index, may produce a normal proportion index value if both measurements have the same degree of deviation from the mean. Therefore, it is important to assess the separate measurements that together make up a proportion index, in order to correctly identify the main measurement(s) responsible for the disproportionate face.

Head type

Cephalic index

The **cephalic index** (index cephalicus) is a numerical expression of the ratio between the **head width** (biparietal diameter) and **head length** (fronto-occipital diameter) of a living person.

Note
The **cranial index**, introduced by the Swedish anatomist Anders Retzius in 1842, is the equivalent of the cephalic index in a dry skull; it is used in craniometry to classify skull types.

The **cephalic index** (CI) is calculated by the formula (Figure 8.2):

CI:
$$\frac{\text{Maximum head width (Eu'-Eu')}\times 100}{\text{Maximum head length (G'-Op)}}$$

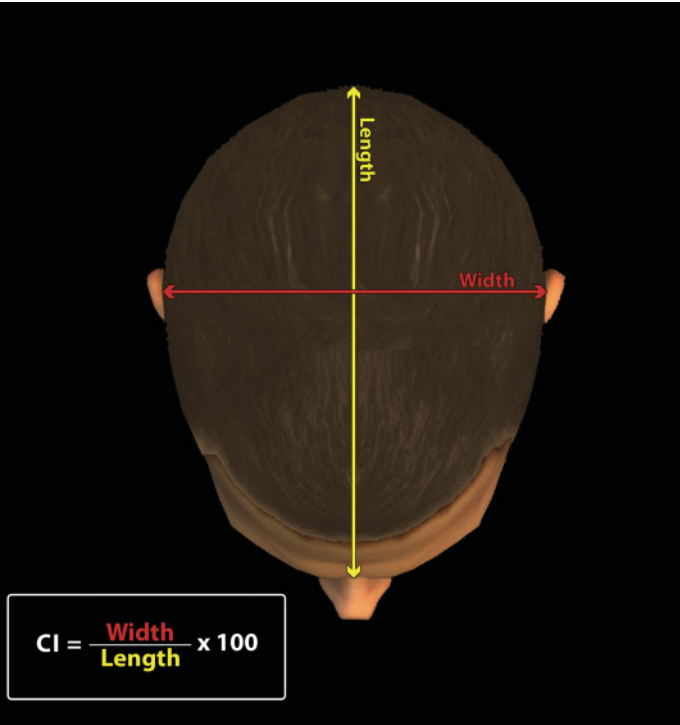


Figure 8.2 Cephalic index.

Where:

- Eurion (Eu’): The most prominent lateral soft tissue point overlying each side of the skull in the area of the parietal and temporal bones.
- Glabella (G’): The most prominent midline point between the eyebrows (identical in position to the bony glabella on the frontal bone).
- Opisthocranium (Op): The point situated in the occipital region of the head, most distant from glabella; it is the most posterior point of the line of the greatest head length.

The **cephalic index** is used in anthropometry to classify head types as (Table 8.1; Figure 8.3):

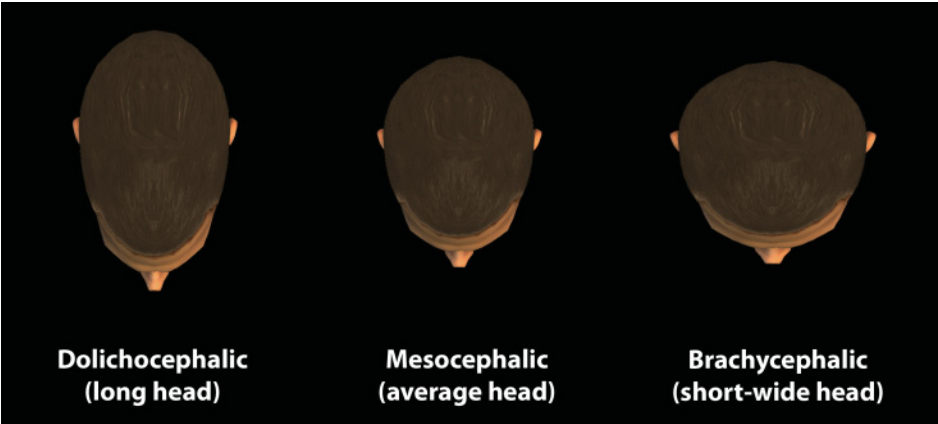
- **Dolichocephalic** (Greek *dolichos*: long; *cephali*: head): The dolichocephalic head type is horizontally long and transversely relatively narrow.
- **Mesocephalic** (Greek *mesos*: average/middle): The mesocephalic head type is the average, lying in between the two extremes.

Table 8.1 Classification of anatomical head types

Head type	Cephalic index	
	Male	Female
Hyper-dolichocephalic (very long head)	≤70.9	≤71.9
Dolichocephalic (long head)	71.0–75.9	72.0–76.9
Mesocephalic (normocephalic; average head)	76.0–80.9	77.0–81.9
Brachycephalic (short-wide head)	81.0–85.4	82.0–86.4
Hyper-brachycephalic (very short-wide head)	85.5–90.9	86.5–91.9
Ultra-brachycephalic (extremely short-wide head)	≥91.0	≥92.0

Index values according to Martin and Saller.⁵

Figure 8.3 Head types.



- **Brachycephalic** (Greek *brachys*: short): The brachycephalic head type is horizontally shorter and transversely wider.

Ethnic differences

The highest cephalic index values occur in the Chinese and the lowest values in African Americans. The larger index values of the Chinese differ significantly from those of whites or blacks (Table 8.2).⁶

Ethnic differences in white individuals

A comparison of the cephalic index of three ethnic groups was undertaken; North American Caucasians, northern European (German) and eastern European (Czech). The index values indicated a mesocephalic head type for both sexes of North American Caucasians and northern Europeans; and a brachycephalic (short-wide) head type for the eastern Europeans.⁶

Head circumference

The head circumference is measured in the horizontal plane around the head, through the glabella and opisthocranium. However, it may be measured across ophryon (the point 'On', in the midsagittal plane, of a line tangent to the upper limits of the eyebrows) rather than glabella in order to eliminate the effect of development of the frontal sinuses and superior orbital rims on head circumference.^{5,7}

Ethnic differences (Table 8.3)

African Americans have the largest and the Chinese have the smallest head circumference for both sexes. The head circumference is slightly larger for blacks than for whites in both sexes.⁶

Facial type: frontal view (norma frontalis)

Facial shape

The initial step in facial analysis involves the examination of the face in frontal view in order to assess the overall facial shape. The variety of facial shapes is almost limitless. However, a simple assessment will allow an overall categorization of the basic facial shape. The basic facial shape in frontal view may be any combination of the following:

- Overall facial shape: round, square or triangular.
- Vertical facial height: reduced, normal or increased.
- Transverse facial width: broad (wide), normal or narrow.

Table 8.3 Head circumference of three ethnic groups

Ethnic group	Head circumference (mm)	SD (mm)
North American white Caucasian:		
Male	569	16
Female	544	15
African American:		
Male	574	16
Female	547	16
Chinese:		
Male	560	14
Female	535	15.5

SD, standard deviation.

Data modified from Farkas.⁶

Table 8.2 Cephalic index of three ethnic groups

Ethnic group	Head width (Eu-Eu) (mm)	SD (mm)	Head length (G'-Op) (mm)	SD (mm)	Cephalic index	SD
North American white Caucasian:						
Male	153	6	194	8	79	5
Female	144	5	185	7	78	4
African American:						
Male	149	7	199	6	75	4
Female	141	6	187	6.5	75	4
Chinese:						
Male	158	5	182	6	87	4
Female	152	5	173	6	88	4

SD, standard deviation.

Data modified from Farkas.⁶



Figure 8.4 Facial height-to-width ratios.

Variations in facial height and width result in an innumerable variety of the three basic facial shapes (round, square and triangular). For example, an oval facial type is a combination of an overall round face combined with increased vertical facial height and/or reduced facial width.

Facial height-to-width ratio/proportion (Figure 8.4)

The relationship of vertical facial height to facial width is an important indicator of overall facial shape. There are three methods of evaluating the vertical facial height-to-width proportion. These may be presented as proportions, percentages or indices:

- **Craniofacial height (vertex-menton) to facial width (Zy-Zy):** The craniofacial height is measured from vertex (the highest point of the head, with the subject in NHP) to menton. Bizygomatic facial width, measured from the most lateral point of the soft tissue overlying each zygomatic arch (zygion), is approximately 60% of vertical craniofacial height.
- **Physiognomical face height (trichion-menton) to facial width (Zy-Zy):** Bizygomatic facial width is approximately 70–75% of vertical facial height. In addition, bitemporal width, measured from the most lateral point on each side of the forehead, is 80–85% of bizygomatic width. Bigonial width, measured from the soft tissue overlying the most lateral point of each mandibular angle (soft tissue gonion), is usually 70–75% of bizygomatic width.
- **Morphological face height (nasion-menton) to facial width (Zy-Zy):** This is otherwise known as the **facial index** (see below).

Facial index

The **facial index** (index facialis or index of the morphological face height) is a numerical expression of the ratio between the facial height (nasion to menton) and the bizygomatic facial width (zygion to zygion) of a living person.

Note

The Renaissance artist Albrecht Dürer described different facial types as observed in frontal view (1528) (Figure 8.5).⁸ The term 'facial index' is thought to have been introduced by J Kollmann in the 1890s in order to classify facial types in dry skulls.

The facial index (FI) is calculated by the formula:

$$\text{FI} = \frac{\text{Facial height (N'-Me')} \times 100}{\text{Bizygomatic face width}}$$

Where:

- Nasion (N'): the soft tissue point overlying the midpoint of the nasofrontal suture.
- Menton (Me'): the lowest point in the midline on the lower border of the chin.
- Zygion (Zy'): the most lateral point on the soft tissue overlying each zygomatic arch.

The facial index is used in anthropometry to classify faces as (Table 8.4; Figure 8.6):

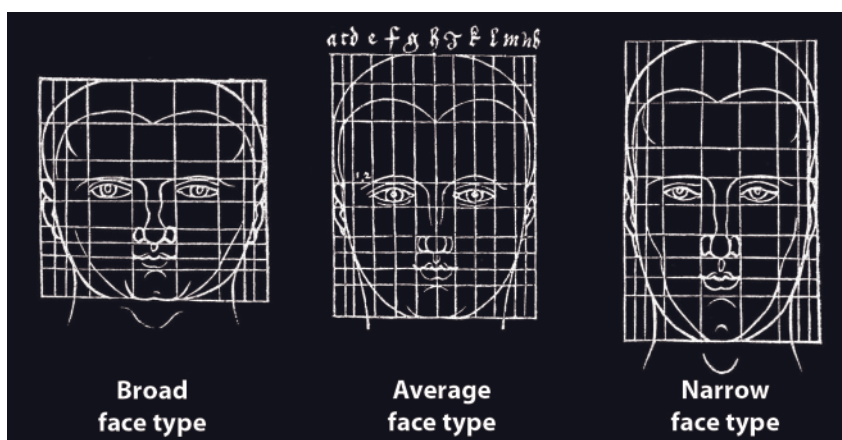


Figure 8.5 Facial types according to Albrecht Dürer. (Modified from Dürer.⁸)

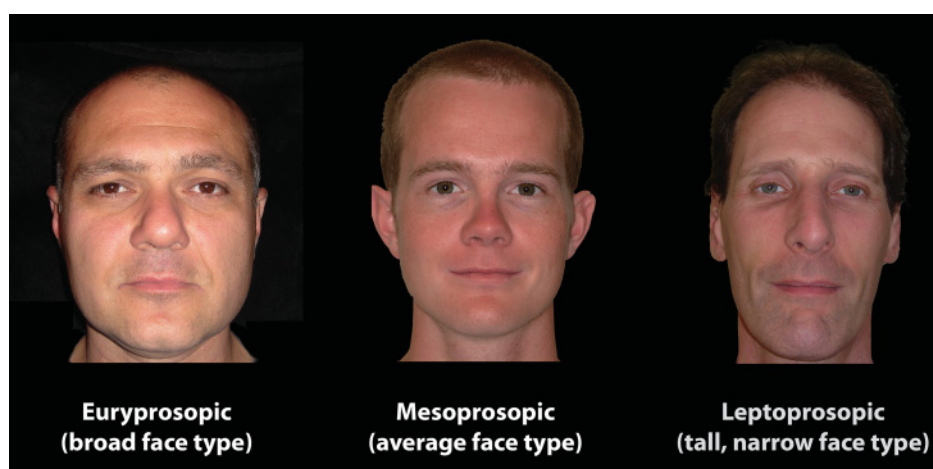


Figure 8.6 Facial types.

Table 8.4 Classification of anatomical face types

Face type	Facial index	
	Male	Female
Hyper-euryprosopic (very broad, short face)	≤ 78.9	≤ 76.9
Euryprosopic (broad, short face)	79.0–83.9	77.0–80.9
Mesoprosopic (normoprosopic; average face)	84.0–87.9	81.0–84.9
Leptoprosopic (tall, narrow face)	88.0–92.9	85.0–89.9
Hyper-leptoprosopic (very tall, narrow face)	≥ 93.0	≥ 90.0

Index values: male according to Garson;⁹ and female according to Martin and Saller.⁵

- **Euryprosopic** (Greek *eury*s: wide; *prosopo*: face): The euryprosopic face type is transversely wider and vertically relatively reduced in height.
- **Mesoprosopic**: The mesoprosopic face type is the average, lying between the two extremes.
- **Leptoprosopic** (Greek *leptos*: thin/narrow): The leptoprosopic face type is vertically relatively tall and transversely narrow.

Facial type: profile view (norma lateralis)

Facial divergence

The term **facial divergence** was introduced by the orthodontist-anthropologist Milo Hellman,¹⁰ although the concept had been described by Albrecht Dürer (1528) (Figure 8.7).⁸ It is essentially a description of the **slope** or **inclination of the face** in the sagittal plane (Figure 8.8). It is determined by the sagittal position of soft tissue pogonion (Pog') and subnasale (Sn) relative to a vertical line dropped from glabella (G'), with the subject's head in

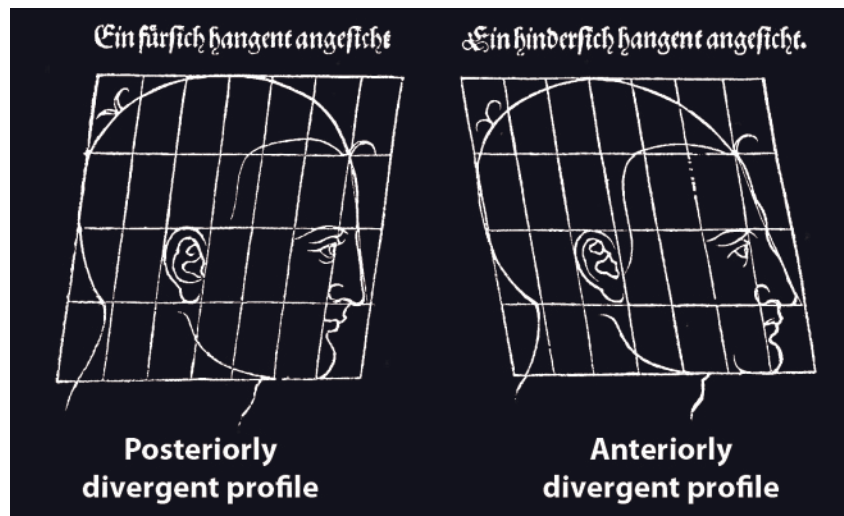


Figure 8.7 Facial divergence according to Albrecht Dürer. (Modified from Dürer.⁸⁾)

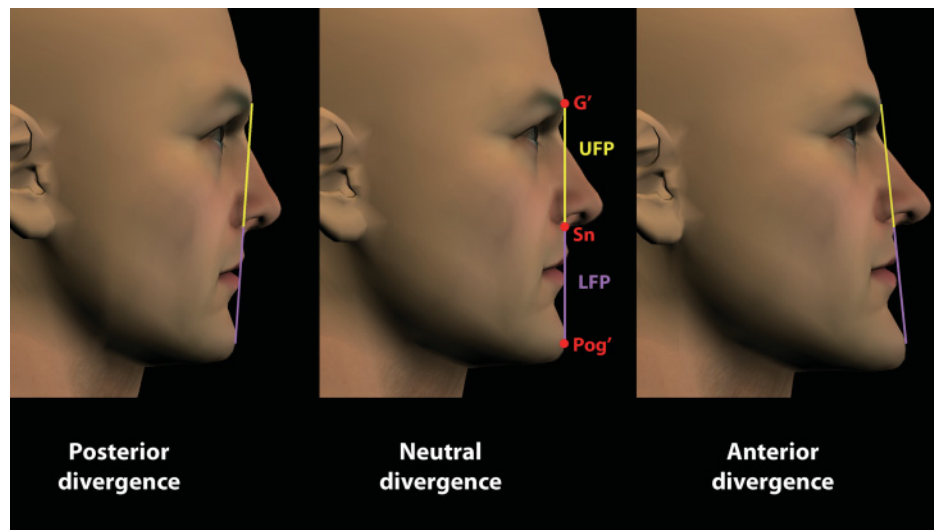


Figure 8.8 Facial divergence.

natural head position. The factor that discriminates and distinguishes facial divergence from profile convexity or concavity is the sagittal position of subnasale (Sn) relative to the G'-Pog' line. In order for the face to diverge anteriorly or posteriorly, yet not to exhibit signs of convexity or concavity, subnasale (Sn) must be on or nearly on the G'-Pog' line; i.e. the **upper facial plane** (UFP, G'-Sn) and the **lower facial plane** (LFP, Sn-Pog') are in a straight line, but diverge anteriorly or posteriorly.

- **Posterior divergence:** The vertical G'-Sn-Pog' line slopes posteriorly, with pogonion posterior relative to glabella in the sagittal plane. This facial pattern is common to individuals of northern European ancestry.
- **Neutral divergence:** The vertical G'-Sn-Pog' line is parallel to the true vertical line, with pogonion in approximately the same position as glabella in the sagittal plane.

- **Anterior divergence:** The vertical G'-Sn-Pog' line slopes anteriorly, with pogonion anterior relative to glabella in the sagittal plane. This facial pattern is common to individuals of African ancestry.

Anthropometric data from North American Caucasian males and females with untreated Class I dental occlusions describing normal facial divergence and ranges of variability has been published.¹¹ Mean values of facial divergence are negative, with the faces being slightly posteriorly divergent. Anterior divergence does not occur until two standard deviations from the mean.

Facial divergence is essentially an ethnic variation in facial profile form. With a straight profile, i.e. no excessive profile convexity or concavity, anterior or posterior facial divergence is compatible with a normal maxillo-mandibular and dental occlusal relationship.

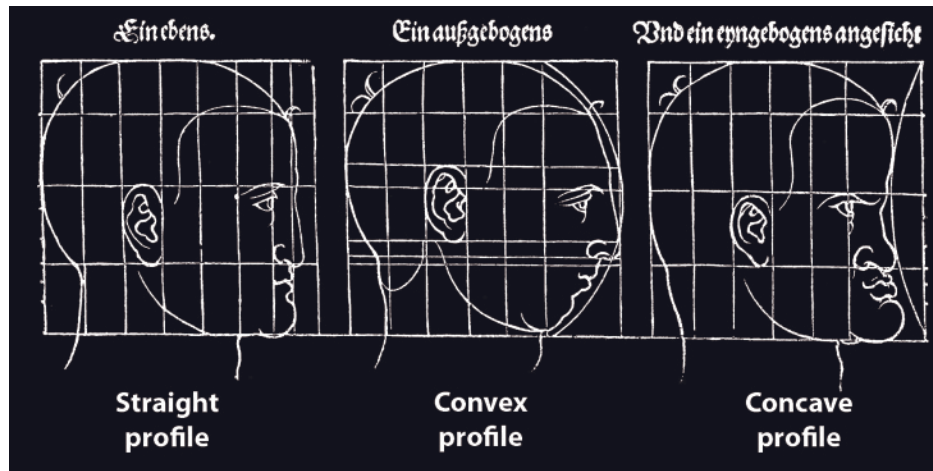


Figure 8.9 Facial profile contour according to Albrecht Dürer. (Modified from Dürer.⁸)

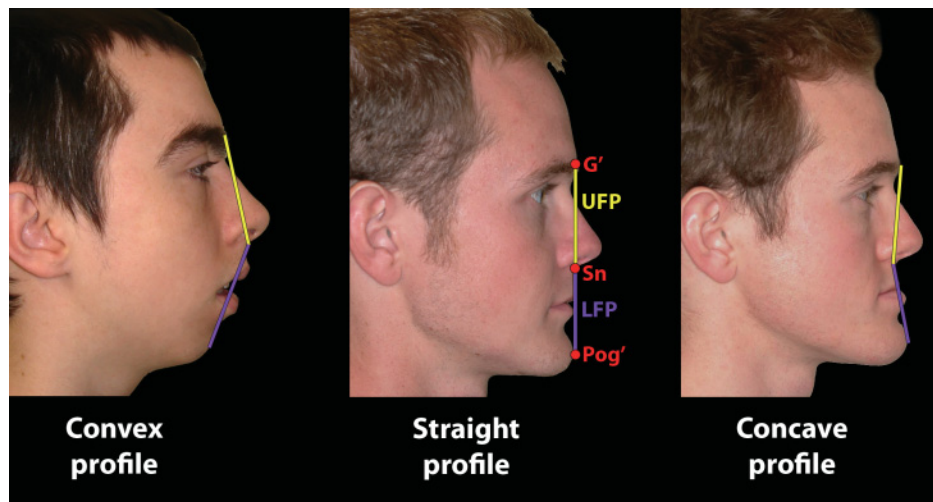


Figure 8.10 Facial profile contours.

Sagittal facial profile contour

The contour of the facial profile may be described as **convex**, **straight** or **concave**. This concept was described by Albrecht Dürer (1528) (Figure 8.9).⁸ With the patient in NHP, the overall contour of the facial profile may be described by the relationship between two lines: the **upper facial plane** (UFP), connecting glabella (G') to subnasale (Sn), and the **lower facial plane** (LFP), connecting subnasale to soft tissue pogonion (Pog'). In a **straight profile**, these two lines form a nearly straight line. Such a facial profile is termed **orthognathic** (Greek *orthos*: correct or straight; *gnathos*: jaw). An angle between these two lines indicates **facial profile convexity** (pogonion behind relative to subnasale in the sagittal plane), or **facial profile concavity** (pogonion ahead relative to subnasale in the sagittal plane). A convex profile indicates a skeletal Class II jaw relationship (and/or sagittal chin deficiency) and a concave profile indicates a skeletal Class III jaw relationship (and/or sagittal chin excess). However, profile convexity or concavity does not of itself indicate whether the maxilla or mandible/chin is at fault (Figure 8.10).

- **Profile convexity:** Indicates a sagittal skeletal Class II jaw relationship. It may be due to sagittal maxillary excess, sagittal mandibular deficiency (and/or sagittal chin deficiency) or a combination of the two.
- **Profile concavity:** Indicates a sagittal skeletal Class III jaw relationship. It may be due to sagittal maxillary deficiency, sagittal mandibular excess (and/or sagittal chin excess) or a combination of the two.

Angle of facial profile convexity (alternative term: facial contour angle) (clinical/soft tissue) (Figure 8.11)

Legan and Burstone¹² described the angle of facial convexity for the soft tissue profile. It is formed by the two intersecting lines, the UFP ($G'-Sn$) and the LFP ($Sn-Pog'$). The mean value is estimated to be $12^\circ \pm 4^\circ$. An increase in the angle in a clockwise direction is positive; anticlockwise is negative. A high positive value suggests facial profile convexity and a Class II skeletal jaw

relationship; a smaller positive value, or a negative value, suggest facial profile concavity and a Class III skeletal jaw relationship. However, the value of this angle does not reveal whether the maxilla or mandible/chin is responsible for the sagittal jaw discrepancy.

Angle of facial profile convexity (cephalometric/skeletal) (Figure 8.11)

Downs¹³ described the angle of convexity, formed by the intersection of line nasion to point A (NA) and line point A to pogonion (A-Pog). Superior extension of the A-Pog line forms an angle with the NA line; if behind the NA line, the angle is read

as positive, indicating a Class II (convex) skeletal profile. A negative angle of convexity indicates a Class III (concave) skeletal profile. Downs provided a range of values from -8.5° to 10° , with a mean of 0° . Again, as with the facial contour angle, the angle of convexity does not determine the localization of the deformity to the maxilla or mandible/chin.

Facial angle (clinical/soft tissue) (Figure 8.12)

The facial angle indicates the relative sagittal prominence of soft tissue pogonion. It is formed by the intersection of the true horizontal plane (or Frankfort Horizontal plane) with a facial

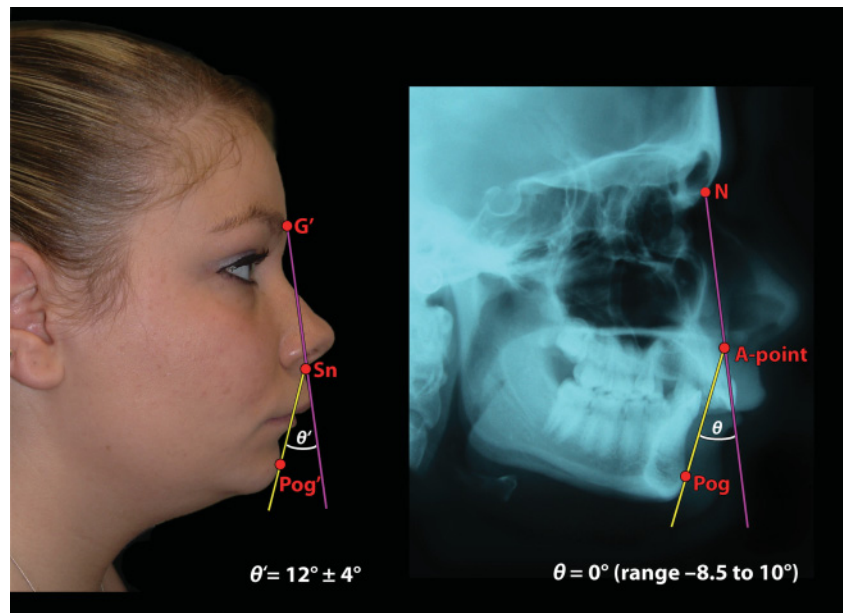


Figure 8.11 Angle of facial profile convexity (facial contour angle).

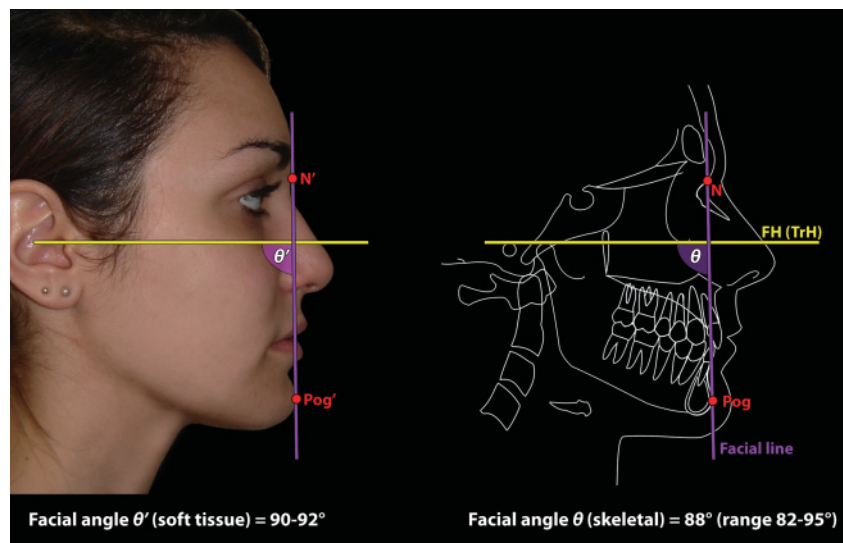


Figure 8.12 Facial angle. FH, Frankfort Horizontal plane, TrH, true horizontal plane.

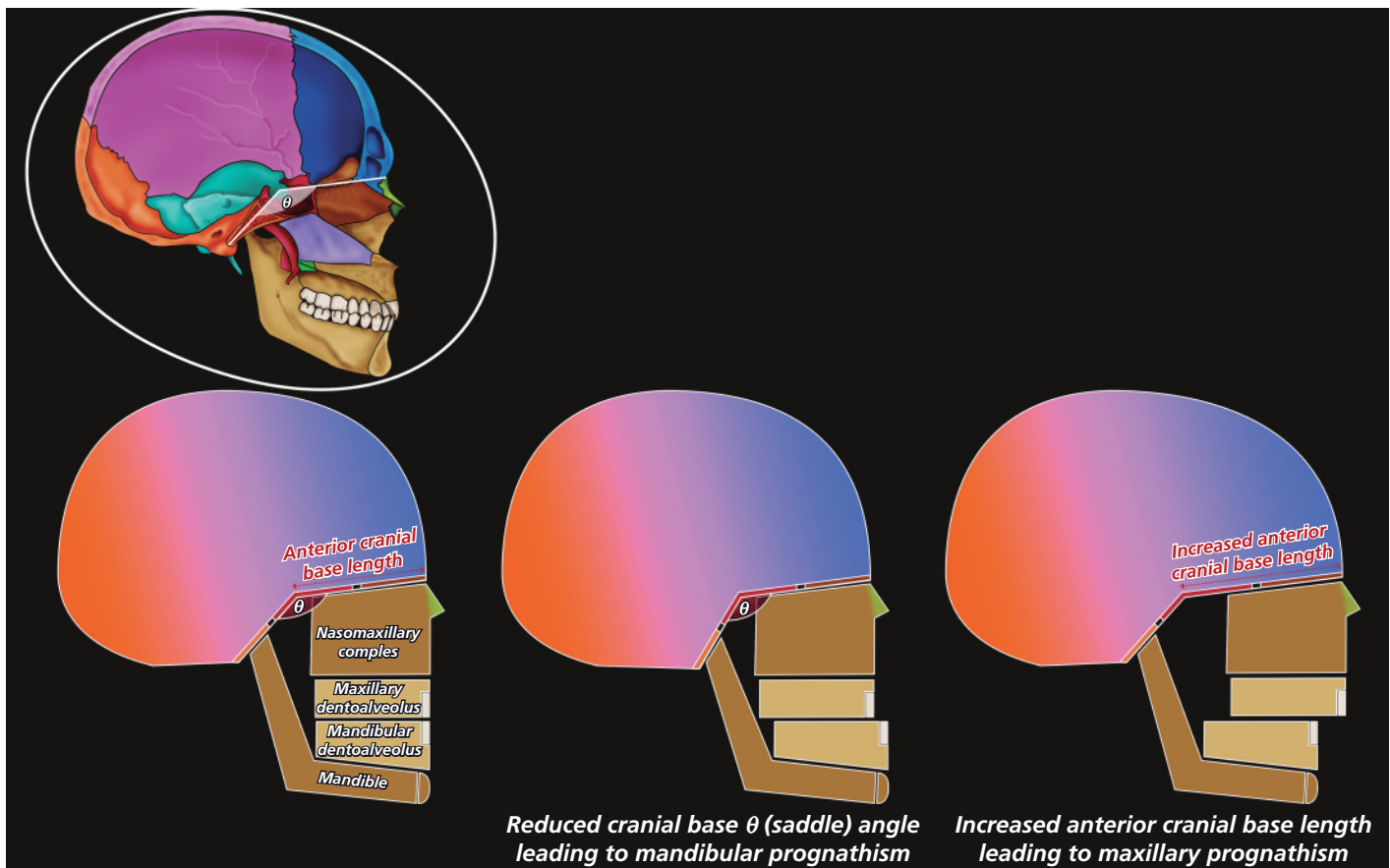


Figure 8.13 The relationship of the cranial base angle (saddle angle) and anterior cranial base length on the jaw relationship.

vertical plane (N'-Pog'). The angle should be 90–92°. A greater angle indicates prominence of soft tissue pogonion; an angle less than 90° indicates retrusion of soft tissue pogonion.

The soft tissue facial angle does not of itself determine the aetiology of the sagittal position of soft tissue pogonion, which may be due to one or a combination of:

- The sagittal position of the mandible (retrognathic or prognathic).
- The size of the mandible (micrognathic or macrognathic).
- The sagittal projection of the chin (retrogenic or progenic).
- The thickness of the soft tissue chin pad (reduced or increased).

Consequently, the facial angle must be used in conjunction with other measurements and analyses.

In addition, when constructing the facial vertical line (N'-Pog'), if the sagittal position of nasion is not acceptable, it may be adjusted to a more ideal position. The alternative is to use soft tissue glabella (G') rather than nasion.

Facial angle (cephalometric/skeletal) (Figure 8.12)

Downs¹³ described the facial angle as the inferior inside angle in which the facial line (N-Pog) intersects the Frankfort Horizontal

plane. Downs found a mean value of 88° with a range of 82–95°. It indicates the relative sagittal position of the mandible/chin to the upper face.

Cranial base angle (Figure 8.13)

The relationship of the anterior to the posterior cranial base is of particular importance in the diagnosis of facial profile contour. This relationship depends on the extent of growth at the **sphenoethmoidal** and **spheno-occipital synchondroses**. The **cranial base angle** (or **saddle angle**) represents the orientation of the anterior cranial base (SN line) relative to the posterior cranial base (S-Ba line).¹⁴ The average adult values (bearing in mind that there is negligible change in this angle after the age of 6 years) for the angle N-S-Ba are:¹⁵

- Male: 129° ± 5°.
- Female: 132° ± 4°.

As such, the cranial base angle is an important determinant of craniofacial form, as it influences the sagittal position of the face relative to the neurocranium and the sagittal prominence of the mandible relative to the maxilla. A significantly increased cranial base angle contributes to a skeletal Class II jaw relationship, whereas a reduced cranial base angle contributes to a skeletal Class III jaw relationship. If nasion is difficult to identify on

a lateral cephalometric radiograph, articulare may be used instead, i.e. the posterior cranial base is drawn between sella and articulare. The average adult values for the angle N-S-Ar are:¹⁵

- Male: $125^\circ \pm 5^\circ$.
- Female: $126^\circ \pm 5^\circ$.

Anterior cranial base length (Figure 8.13)

The **anterior cranial base length**, measured from sella to nasion, may also influence the jaw relationship. For example, increased anterior cranial base length may lead to a Class II jaw relation-

ship, with the maxilla ahead of the mandible in the sagittal plane, whereas reduced cranial base length may lead to a Class III jaw relationship, with the maxilla behind the mandible in the sagittal plane. The average adult values for the anterior cranial base length are:¹⁵

- Male: 72 ± 3 mm.
- Female: 67 ± 2 mm.

Parasagittal facial profile contour

An additional and extremely important consideration is the description of the parasagittal profile (Figure 8.14). It is necessary to evaluate the sagittal relationships of the soft tissues from the **infraorbital area** to the **paranasal area** to the **parasymphyseal area**. For example, maxillary hypoplasia may lead to lack of bony support and flattening in the infraorbital region and paranasal hollowing; with a normal parasymphyseal area, this will lead to the appearance of a concave parasagittal profile.

Vertical facial profile form

The **directional pattern of facial growth** has a significant effect on facial profile form. Deviations from the normal pattern of jaw growth may be in a predominantly *vertical* or *horizontal* direction.

Vertical facial growth pattern and hyperdivergent facial type (Figure 8.15)

Alternative terms are **hyperdivergent facial growth pattern** (referring to the excessive divergence of the maxillary, occlusal and mandibular planes in relation to each other and to the anterior cranial base).¹⁶ Such a pattern of growth leads to a hyperdivergent facial type, alternatively termed a **high angle** patient (referring to the increased mandibular plane angle), **long face deformity** or **long face syndrome**.¹⁷ If the hyperdivergent growth

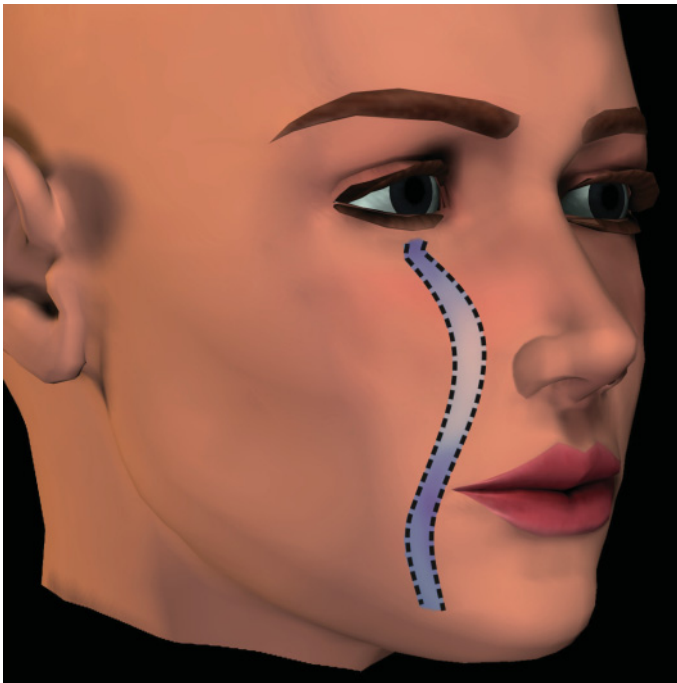


Figure 8.14 Parasagittal profile contour.



Figure 8.15 Hyperdivergent, 'high angle' facial type.

is the primary aetiology to an anterior open bite, the terms **skeletal open bite** or **apertognathia** (Latin *apertus*: open; Greek *gnathos*: jaw) may be used.^{18,19} The maxilla rotates downward and backward (posterior vertical maxillary excess), as does the mandible during growth. This leads to reduced sagittal projection of the chin. Such a vertical facial growth pattern will tend to be associated with a posterior pattern of mandibular growth rotation.

Note

In this context, the term 'long face' refers to an increase in facial height and would thereby be more correctly referred to as a 'tall face', as length is a term used to describe measurements in the sagittal plane of the cranio-facial complex. However, the term 'long face' still tends to be used in the clinical setting. In addition, it is important to bear in mind that a patient may have increased vertical face height but with average vertical proportional relationships between the facial thirds. It is only when *disproportion* exists between the vertical facial thirds that a 'long face' deformity is said to be present.

Horizontal facial growth pattern and hypodivergent facial type (Figure 8.16)

Alternative terms are **hypodivergent facial growth pattern** (referring to the almost parallel orientation of the maxillary, occlusal and mandibular planes in relation to each other).¹⁶ Such a pattern of growth leads to a **hypodivergent facial type**, alternatively termed a **low angle** patient (referring to the reduced mandibular plane angle), '**short face deformity**' or **short face syndrome**.²⁰ If the hypodivergent growth is the primary aetiology to a deep incisor overbite, the term **skeletal deep bite** may be used.¹⁹ An element of vertical maxillary deficiency often coincides with mild mandibular retrognathia, leading to a reduced lower anterior face height, a reduced mandibular plane angle and mandibular overclosure.²¹ Such hypodivergent facial growth patterns will tend to be associated with an anterior pattern of mandibular growth rotation.

Note: High angle (hyperdivergent) versus low angle (hypodivergent) profiles

A 'high angle' is a descriptive term for a patient with an increased mandibular plane angle; this *usually correlates with* an increased lower anterior facial height, often together with a leptoprosopic (tall, narrow) facial type. The facial growth pattern will tend to be vertical in direction, often associated with a posterior pattern of mandibular growth rotation.

A 'low angle' is a descriptive term for a patient with a reduced mandibular plane angle; this *usually correlates with* a reduced lower anterior facial height and a euryprosopic facial type. The various skeletal planes tend to be almost parallel to one another. The facial growth pattern will tend to be horizontal in direction, often associated with an anterior mandibular growth rotation.

The terms **hyperdivergence** and **hypodivergence** were suggested by the orthodontist Fred F Schudy (1964),¹⁶ referring to the two extremes of vertical facial growth pattern, as opposed to the two extremes of sagittal growth pattern, i.e. prognathism and retrognathism.

A number of clinical and cephalometric parameters may be evaluated in order to analyse vertical facial profile form. These are described below.

Mandibular plane angle (clinical)

This is formed by the angle between the mandibular plane (tangent to the inferior border of the mandible) and the true horizontal (or Frankfort Horizontal) plane. The advantage of this variable is that it may be measured clinically. The mandibular plane may be assessed clinically by placing a finger or dental mirror handle along the inferior lateral border of the mandible (Figure 8.17). This angle may be assessed both clinically and cephalometrically.

The following values for the **Frankfort-mandibular planes angle (FMPA)** have been reported:

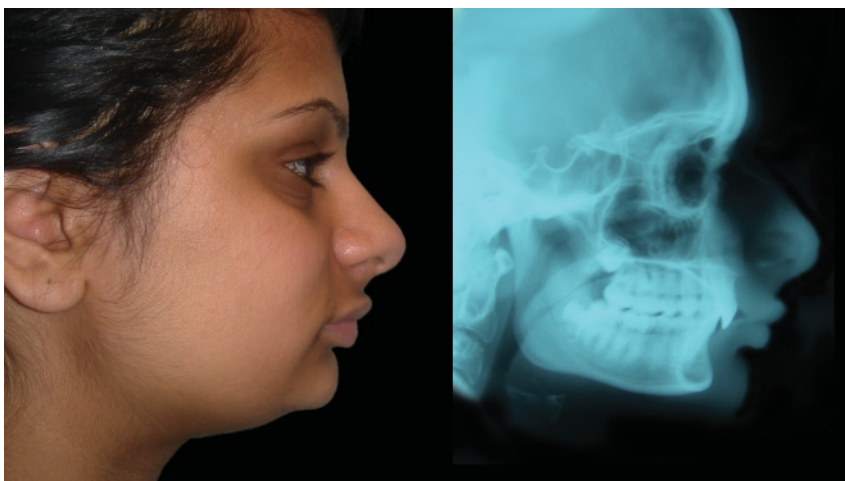


Figure 8.16 Hypodivergent, 'low angle' facial type.

- Downs:¹³ 22° (range $17-28^\circ$).
- Tweed:^{22,23} $25^\circ \pm 3^\circ$. Tweed reported this angle to be a useful indicator of the direction of lower facial growth. An angle above 30° suggests increased vertical facial growth and clockwise rotation (in the direction of mouth opening) of the mandible.
- Ricketts:²⁴ $26^\circ \pm 4^\circ$.
- Riolo et al.:²⁵ $29^\circ \pm 5^\circ$ in males; $26^\circ \pm 3^\circ$ in females.
- Bhatia and Leighton:¹⁵ $22^\circ \pm 6^\circ$ in males; $23^\circ \pm 5^\circ$ in females.

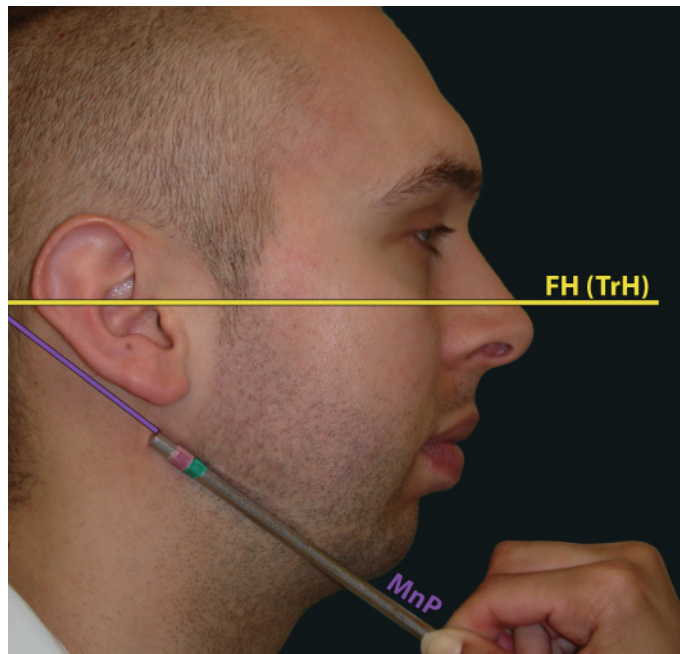


Figure 8.17 Mandibular plane angle (clinical). FH, Frankfort Horizontal plane; TrH, true horizontal plane.

Mandibular plane angle (cephalometric) (Figure 8.18)

This indicates the difference between the anterior and posterior facial height. The mandibular plane is drawn between gonion and menton, or may be drawn as a tangent to the inferior border of the mandible.

- **SN-MPA:** Steiner related the mandibular plane to the anterior cranial base, describing the SN to mandibular plane angle, giving a mean value of 32° .²⁶
- **Maxillary-mandibular planes angle (MMPA):** The mandibular plane may also be related to the maxillary (palatal) plane. The size of this angle is determined by the ratio of anterior to posterior intermaxillary heights, providing a measure of the divergence of the intermaxillary space anteriorly. Variations are usually due to the inclination of the mandibular plane, but may also be due to the inclination of the maxillary plane. The suggested mean value of approximately $26^\circ \pm 5^\circ$ has been verified.^{15,25}

Gonial angle (Ar-Go-Me) (Figure 8.19)

This is a measure of the angle formed between the slope of the posterior border of the mandibular ramus and the mandibular plane. It helps to describe the *form of the mandible*, in particular the relationship between the ramus and the body. It is highly correlated with the mandibular plane angle.

- Riolo et al.²⁵ described the US normal values:
 - Male: $124^\circ \pm 6^\circ$.
 - Female: $122^\circ \pm 4^\circ$.
- Bhatia and Leighton¹⁵ described the UK normal values:
 - Male: $126^\circ \pm 6^\circ$.
 - Female: $128^\circ \pm 5^\circ$.

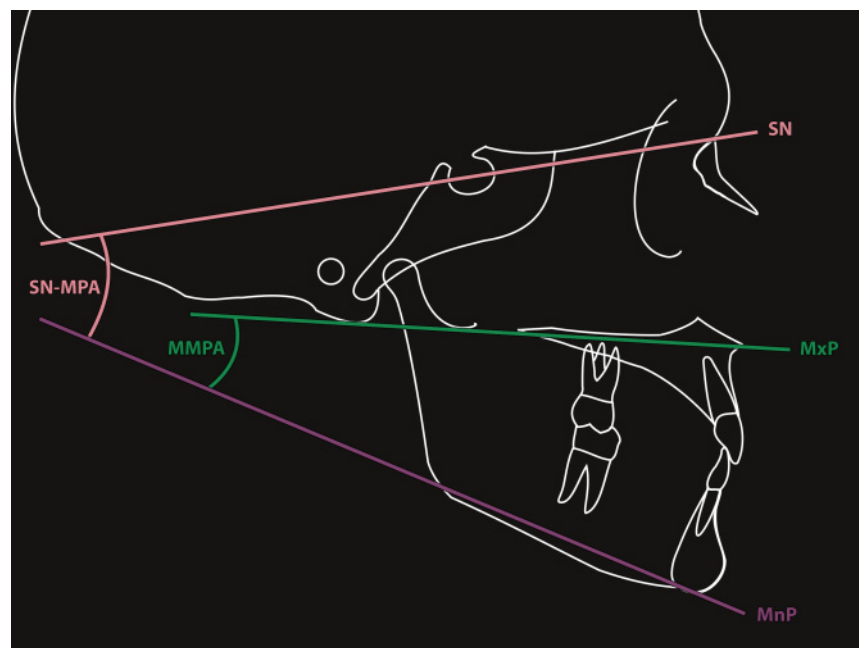


Figure 8.18 Mandibular plane angle (cephalometric). MxP, maxillary plane; MnP, mandibular plane; SN, sella-nasion plane.

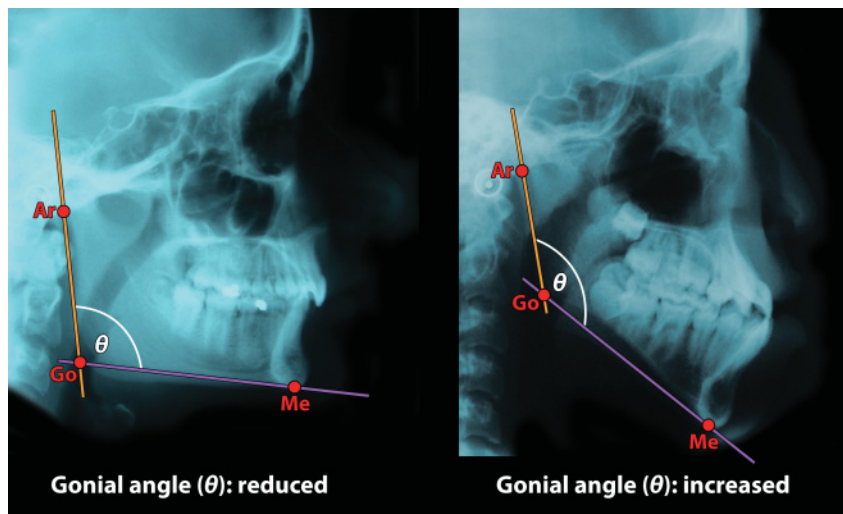


Figure 8.19 Gonial angle.

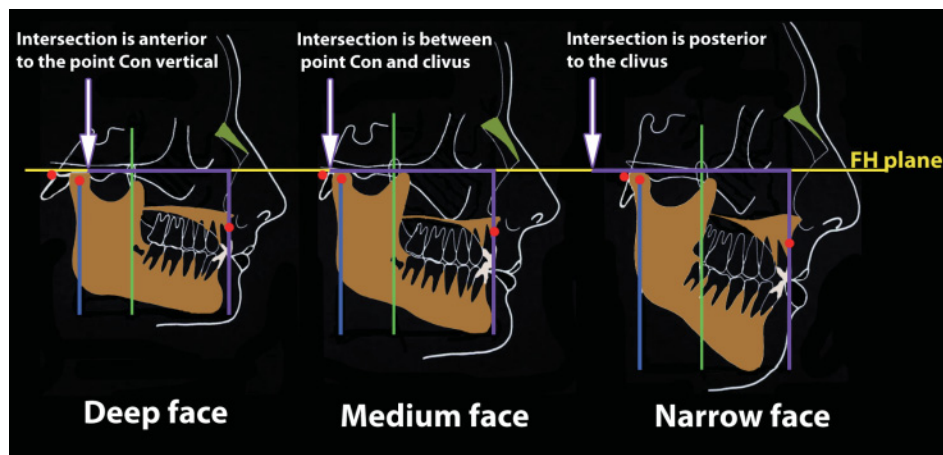


Figure 8.20 Facial height to horizontal facial depth ratio. FH, Frankfort Horizontal. (Modified from Bimler.²⁷)

An increased gonial angle is associated with posterior (backward) mandibular growth rotation, and a reduced gonial angle is associated with anterior (forward) mandibular growth rotation.

Convergence of horizontal facial planes (Sassouni analysis)

An extremely useful method of evaluating vertical facial relationships is to analyse the relative orientation of the horizontal planes of the face and their posterior region of convergence. This has been described in detail in Chapter 7.

Facial height to horizontal facial depth ratio (cephalometric) (Figure 8.20)

The orthodontist Hans Bimler (1958) introduced the **suborbital facial index** relating suborbital facial height to horizontal lower facial depth in profile view, using the lateral cephalometric

radiograph.²⁷ The horizontal reference line is the Frankfort plane. Anterior and posterior limits to the face are determined by dropping verticals perpendicular to the Frankfort Horizontal plane through maxillary A-point and the condylar midpoint (Con; the centre of the head of the condyle, alternatively termed capitulare). The posterior limit of the maxilla may be determined by dropping a perpendicular from the pterygomaxillary fissure.

The index is established by measuring the anterior suborbital facial height and transferring the measurement horizontally to the Frankfort Horizontal plane (horizontal facial depth). The point of intersection gives the facial type:

- Deep face (increased depth to height ratio): The intersection is anterior to the point Con vertical and horizontal facial depth is greater than facial height.
- Medium face (depth to height ratio ~1:1): The intersection is between point Con and the clivus.

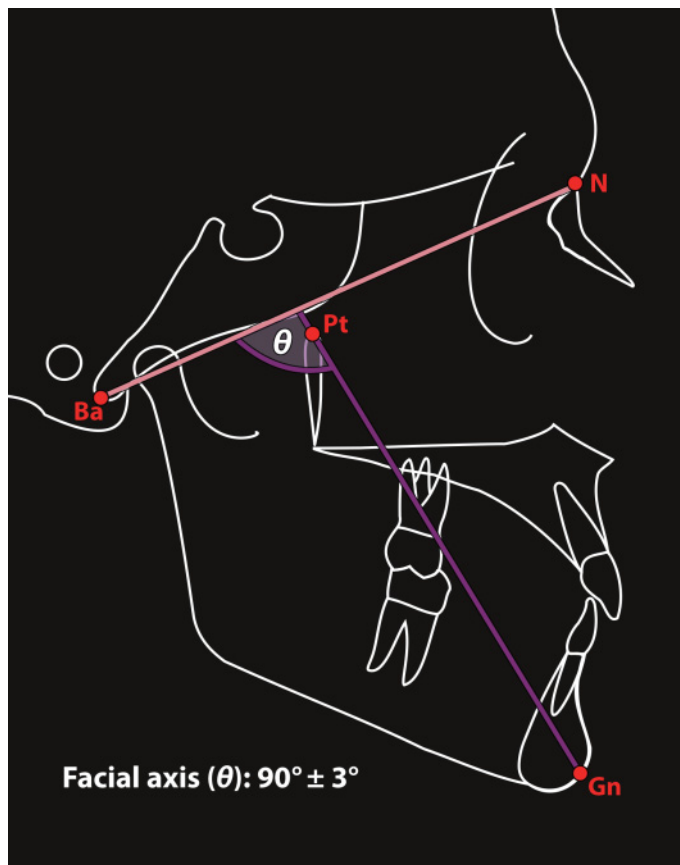


Figure 8.21 Facial axis.

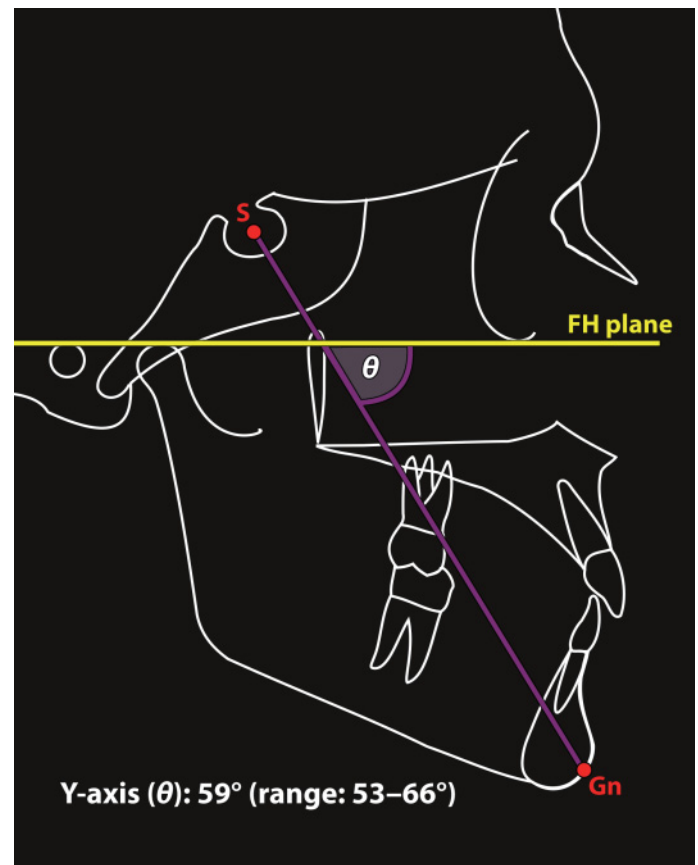


Figure 8.22 Y-axis. FH, Frankfort Horizontal.

- Narrow face (reduced depth to height ratio): The intersection is posterior to the clivus and facial height is greater than horizontal facial depth.

Facial growth axes (cephalometric)

Facial axis (Figure 8.21)

Ricketts²⁴ described the **facial axis** as the posterior angle formed by the intersection of the basion-nasion plane and the Pt-Gn line. It describes the direction of growth of the mandible/chin and is said to remain relatively constant with age in patients with a normal growth pattern.

- The norm is $90^\circ \pm 3^\circ$.
- A reduced angle, below 90° , indicates a vertical growth pattern and a leptoprosopic (tall, narrow face) facial type.
- An increased angle, above 90° , indicates a horizontal growth pattern and a euryprosopic (broad, short face) facial type.

Y-axis (Figure 8.22)

Downs¹³ described the **y-axis** (or y-growth axis) as the anterior angle formed by the intersection of the S-Gn line with the

Frankfort Horizontal plane. It describes the position of the chin in relation to the upper face.

- The norm is 59.4° (range 53–66°).
- A reduction in the y-axis in serial radiographs signifies a horizontal growth pattern.
- An increase in the y-axis in serial radiographs signifies a vertical growth pattern.

Facial curves and curvilinear relationships

‘There are no straight lines in Nature.’

Sir Harold D Gillies (1957)²⁸

The importance of **flowing curves** to the appreciation of beauty in nature was suggested by the fourteenth-century Persian poet-scholar Hafez of Shiraz. Such flowing curves were part of the beauty of geometry and were described as present throughout nature, but particularly important in the beautiful female face; the gentle waves in the hair, the curve of the eyebrows and eyelashes, the lips, chin and so on. Straight lines and sharp angles tended to diminish beauty, whether in geometry or the female facial form.

Curvilinear relationships – frontal and profile views

The facial surface has a large number of points, or **surface landmarks**. As described in Chapter 7, these points may be defined in that they are visible to the human eye, but are not divisible into parts, e.g. nasion, pronasale, etc. Points or landmarks joined together continuously in a row form a **line**. A line may be defined in that its length may be divided into parts, but it is so slender that it cannot be divided in width. Lines on the facial surface are almost never straight, but tend to **curve**, hence may be termed **facial contour lines**. If many such contour lines are joined closely together, they will create a **surface**. Lines and surfaces may curve outwards, resembling the outside of a sphere; this is termed **convexity**. Conversely, they may curve inwards, resembling the inner surface of eggshells; this is termed **concavity**. The interrelation of these undulating facial peaks and troughs may be referred to as **facial curvilinear relationships**.

Angularity of facial contour lines

‘the face in which the surfaces are so joined together that pleasing lights pass gradually into agreeable shadows and there are no very sharp angles, we may rightly call a handsome and beautiful face.’

Leon Battista Alberti, *De Pictura* (‘On Painting’, 1435)²⁹

Facial contour lines are almost never straight, but are **curvilinear** in form. These lines curve to various extents over underlying dentoskeletal prominences and at the transitions between various facial regions. The **facial contour line angles** may be described as having (Figure 8.23):

- **Reduced angularity:** Other terms are ‘soft’, ‘feminine’, ‘blunt’ or ‘smooth’. Such contour line angularity is more common in the *female* facial form.
- **Increased angularity:** Other terms are ‘hard’, ‘masculine’ or ‘sharp’. Such contour line angularity is more common in the *male* facial form.

Male faces tend to exhibit greater angularity, whereas female faces have reduced angularity and increased ‘softness’ to facial outlines. Increased angularity of the facial curvilinear contour lines in women tends to diminish attractiveness. However, in terms of masculinity or femininity, the *acuteness* or *obtuseness* of the line angles is not as important as the ‘smoothness’ of the *transition between the lines*, e.g. an increased (obtuse) gonial angle may still appear masculine if the transition between the posterior ramus plane and the inferior border of the mandible is sharp with increased angularity; conversely, a reduced (acute) gonial angle may appear feminine if the transition is smooth rather than sharply angled.

Facial profile curves and ‘S-shaped’ curvilinear considerations

The evaluation of the lateral view of the face, termed the facial profile, is highly significant in facial aesthetic analysis. This is particularly true of the curvilinear considerations of the soft tissue profile. **Calvin S Case** (1847–1923), a physician and orthodontist, described the importance of the **facial profile curves** in detail (Figure 8.24).³⁰ He emphasized the curvilinear form of three specific regions:

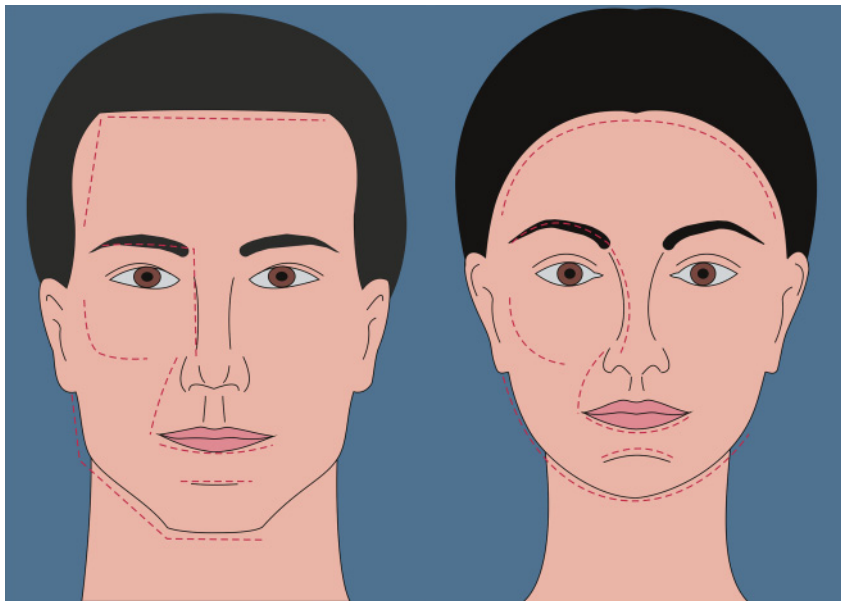


Figure 8.23 Facial contour line angles in men and women.

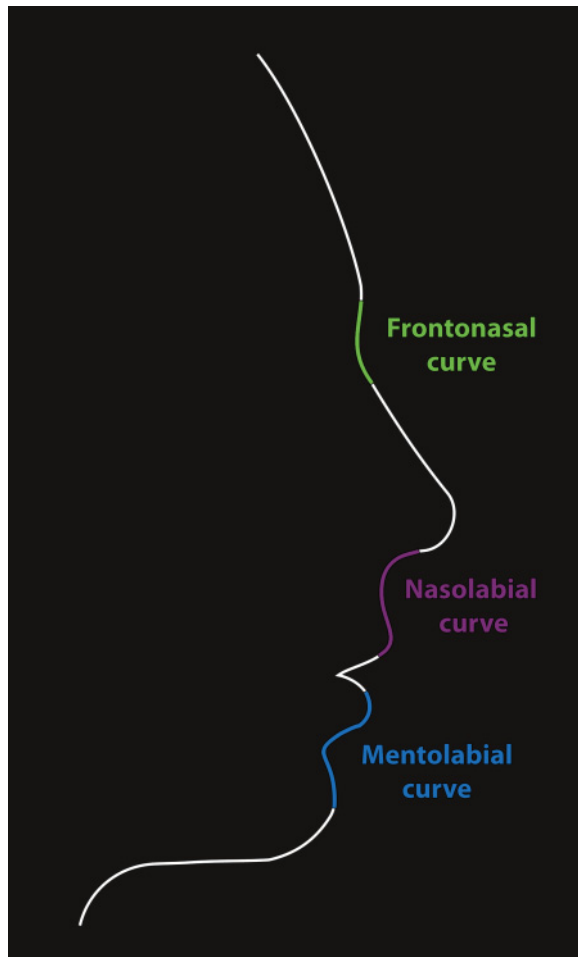


Figure 8.24 Facial profile curves. (Redrawn from Case.³⁰)



Figure 8.25 'S-shaped' curvilinear considerations. (Modified from Peck and Peck.³¹ with kind permission of the EH Angle Education & Research Fdn., Inc.)

- **Frontonasal curve:** This is the uppermost curve of the facial profile, joining the nasal dorsum and radix to the glabellar region. The form of this curve provides much of the character of the upper face.
- **Nasolabial curve:** Below the nose, the upper lip should have a 'graceful' concave curve from the base of the nasal columella to the border of the upper lip.
- **Labiomental (mentolabial) curve:** This forms the most inferior curve of the front of the face, giving character to the chin and forming a 'graceful' arc from the chin to the border of the lower lip, with the *mandible in the rest position and the facial soft tissues in repose*.

Peck and Peck³¹ referred to the attractive appearance of these facial profile curves as **profile flow**, which may be 'visualized as a series of waves or reversed "Ss" on the right profile (Figure 8.25).' These curves are 'S' shaped when viewing the left facial profile, and reverse 'S' shaped when viewing the right profile. They added: 'Irregularities or acute curves, though often tolerated especially in males, tend to disrupt an otherwise harmonious profile. A nasal hump or very angular lips, for example, concentrate the observer's attention, much like a discoloured

anterior tooth focuses our attention away from the rest of the teeth.' It is therefore incumbent on the diagnosing clinician to accurately evaluate the **sinuous** ('S' and reverse 'S' shaped curves) curvilinear relationships of the facial profile.

Contour defects

The morphology and **soft tissue contour** of a number of facial parameters consists of a series of *curved* lines. In addition, as already described, the *transitions* between various facial parameters consist of smooth flowing, *curvilinear* forms. Interruptions in these curvilinear lines and surfaces are described as **contour defects**. For example, the **brow-nasal tip aesthetic contour line**, which extends from the curve of the eyebrow to the nasal tip, should be smooth, gently curving and devoid of contour defects bilaterally (Figure 8.26). Fractures or deviations of the nasal dorsum are visualized as nasal contour defects, which may be unattractive. When excessive and displeasing to the patient, correction of such contour defects to conform to the smooth flowing aesthetic lines may be required.

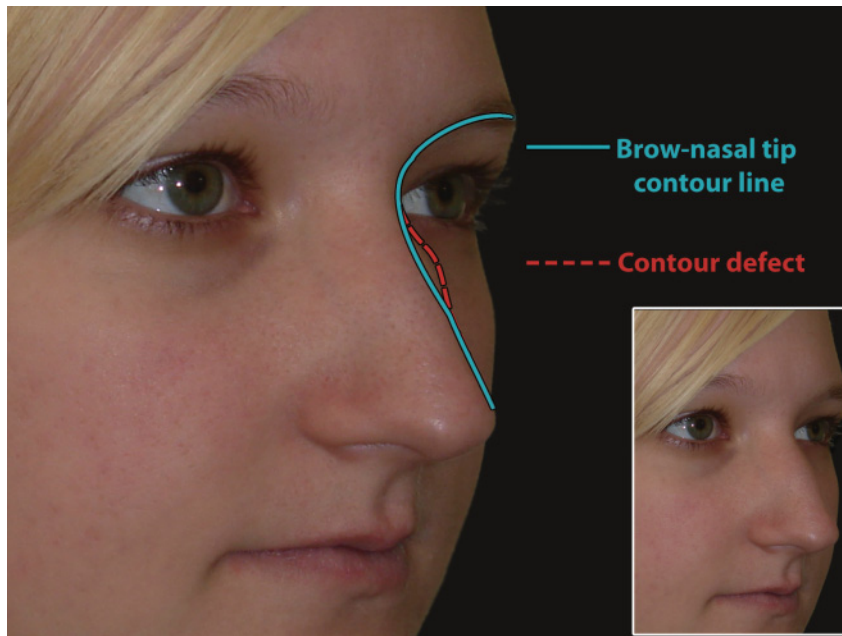


Figure 8.26 Nasal contour defect.

Sexual variation: the main differences between male and female faces

Sexual variation in facial appearance refers to the typical structural and morphological differences between male and female faces.

Note

An alternative term is **gender variation**. However, the words gender and sex are typically used in slightly different ways: **gender** tends to refer to social or cultural differences whereas **sex** refers to biological differences.

There is no one feature that distinguishes the male from the female face; it is an overall pattern that distinguishes the male and female face. In addition, some women may have rather masculine facial features, whereas some men have rather feminine features.

The main differences in skull and facial morphology between males and females tend to occur during the pubertal growth spurt. The male and female faces grow more disparate at this time and the distinctions remain during the childbearing years, though similarities tend to increase again in old age.

The main differences between the male and female face are listed below.

Size: Adult males tend to be larger than females due to faster rates of growth during puberty and a longer period of growth. Nevertheless, there is considerable range of variation in both sexes.

Overall shape: The female face tends to be more oval in shape, with the two rounded corners of the hairline coming down to the single point of the chin. The male face has a more square appearance with the lateral aspect of the square-shaped forehead and 'M' shaped hairline continuing down to the wide, square gonial angles. The lower anterior face height is relatively greater in the male face, usually because of the relatively greater upper lip height and increased chin height.

Cranium: The male cranium tends to have relatively thicker bones in the neurocranial vault and the male skull overall has more pronounced muscle origins and insertions.

Hairline: The male hairline tends to have an 'M' shape as it often recedes laterally, just above the temples.

Forehead inclination: The male forehead tends to slope posteriorly; the female forehead is usually more vertical.

Brow ridge: The frontal sinuses are larger and the glabellar region and superciliary arches are more pronounced; men's eyes thereby *appear* more deep-set. The superior margin of the orbit is more angular and square shaped.

Eyebrows: Male eyebrows tend to be horizontally straight, relatively thick and positioned on or just inferior to the orbital rims. Female eyebrows are generally higher, just above the orbital rims and are usually shaped as a gentle arc.

Nose: The male nose is proportionately larger than the female nose. Women tend to have smaller noses with more concave dorsal morphology in profile view, whereas men's noses are relatively larger and more pronounced.

Cheekbones: Female cheekbones are less prominent but may *appear* more prominent due to reduced projection of the surrounding areas.

Lip morphology: Female vermilion exposure tends to be greater, due to an increased proportion of vermilion height to overall lip height.

Mandible: The male mandible is relatively larger with broader bigonial width. The gonial region is more angular – the ramus drops down relatively vertically from the ear region and turns anteriorly with a relatively pronounced gonial angle. The female ‘jaw line’ tends to have a gentler curve from the ear region to the chin.

Chin: In frontal view, the male chin is broader with a more square shape; female chins tend to be rounded and narrow. In profile view, the male chin tends to be more pronounced due to greater prominence of the mandibular symphysis (bony chin).

‘Ethnic’ variation: considerations in facial aesthetic evaluation

The ‘ideal’ facial proportions described by classical sculptors were later refined by Renaissance artists. However, modern proportional relationships employed in diagnosis and treatment planning are primarily based on contemporary anthropometric and cephalometric studies, undertaken mainly in the last few decades. The majority of available data stems from white Caucasian populations of northern European descent,^{15,25} though data on various ethnic groups are steadily becoming available.³² Nevertheless, *ethnic differences should be taken into consideration when evaluating a patient for facial aesthetic and/or reconstructive surgery.*

Historical background

The concept of ‘racial groups’ within the human population dates back to the nineteenth century. The German physiologist and anatomist, **Johann Friedrich Blumenbach** (1752–1840), considered the founder of physical anthropology, developed a ‘racial classification’, that grouped modern humans into five broad categories (Caucasian, Mongoloid, Malayan, Ethiopian and American) based mainly on craniometric measurements. He introduced the term **Caucasian** (or Caucasoid) to include a broad group of peoples in Europe, western Asia, and parts of the Indian subcontinent and North Africa. Blumenbach believed that this ‘Caucasian race’ originated in the Caucasus region, a mountain range lying between the Caspian Sea and the Black Sea. According to Blumenbach, the term Caucasian included peoples whose skin colour ranged from light, e.g. in northern Europe, to dark, e.g. in parts of north Africa and India. The term Mongoloid related to the indigenous people of eastern and south-eastern Asia, and the Arctic region of North America.

The classification of Blumenbach is outdated and the categories are no longer considered scientific. In fact, attempts to classify human racial types are today recognized as scientifically baseless. Evidence from the modern science of genetics has demonstrated that humanity was never divided into distinct lineages. Steve Jones, Professor of Genetics at University College London, writes:³³

‘The genes do show that there are no separate groups within humanity.’

The British biologist Sir Julian Huxley (1887–1975) suggested that the word ‘race’ be replaced with **ethnic group**. He wrote:³⁴

‘The word “race”, as applied scientifically to human groupings, has lost any sharpness of meaning. Today it is hardly definable in scientific terms, except as an abstract concept ...’

Considerations in facial aesthetic evaluation

Variation in craniofacial morphology is present within and between populations. As with the human genotype, it has been demonstrated that variation in human cranial morphology is actually far greater *within* than *between* populations.³⁵ Interestingly, the most marked differences in cranial morphology occur in Africa. However, *some tendencies are evident when comparing average facial morphology from populations of different geographical origin.*

The science of genetics has put an end to the concept of race. This would suggest that such variations in facial morphology may be best termed **geographical variation**, suggesting indigenous geography, environment and climate as the primary aetiology of the facial variation between different populations that has occurred over time. Nonetheless, until this term is better accepted, such categories of facial morphological variability may be subcategorized as those of ethnic groups. For example, there are 56 known ethnic groups in China alone. Northern and southern Chinese have distinct differences in their facial morphological features. Northern and eastern Europeans are ‘white Caucasians’, but again with markedly different facial features and proportions. When planning treatment, the clinician must take into account the data, when they are available, for normative values and normal ranges of variation within each major ethnic group. In addition, the clinician must not lose sight of the fact that there will be patients requesting features from a different ethnic group possibly due to cultural influences, with potential psychological implications.

Note

The greatest differences among and between ethnic groups seem to be in the dentoalveolar region.³⁶

Therefore, it is useful to compare a patient’s craniofacial morphology to the average for their nearest ethnic group. When craniofacial anthropometric and cephalometric data from a specific ethnic group are not available, the data from the nearest ethnic group may be employed to provide guidelines for diagnosis and treatment planning. Clinicians must understand the characteristic features of different ethnic groups and appreciate ethnic variation in order to aim to create a natural appearance. Yet it remains prudent for analysis and treatment planning to be *individualized*, i.e. each patient must be evaluated as an individual.

Note

The term 'Oriental' has been used in the past to refer to individuals of Far Eastern descent. In US English, **Asian** is the standard accepted term in modern use. In British English, where **Asian** tends to denote people from the Indian subcontinent, specific terms such as **Chinese** or **Japanese** are more likely to be employed. As a rule, it is far more accurate and clinically useful to refer to *specific* ethnic groups, particularly when normative data for that population are available.

Facial ageing

'it is not everybody's good fortune to grow more graceful and beautiful in advancing age.'

Sir Harold D Gillies (1957)²⁸

The ageing process is an inherent part of life. Relatively characteristic changes occur to the facial appearance in each decade of life, which makes individuals 'look their age'. However, in some individuals a number of factors may contribute to an *acceleration* of the ageing process; as such, an individual may appear 'older than their years'. These factors may include excessive alcohol and tobacco consumption, chronic exposure to the sun and prolonged illness and stress.

An understanding of the ageing process is important for two reasons:

- It permits the clinician's goal to help restore youthful features (termed **facial rejuvenation**), which correspond to the patient's chronological age, providing a natural appearance.
- It helps to prevent clinical procedures that may lead to an aged appearance, particularly in relation to a patient's future appearance, e.g. excessive intrusion of maxillary incisor teeth in a younger patient may lead to reduced incisor exposure, particularly as the upper lip sags with age.

Facial ageing affects the soft tissue integument and the underlying dentoskeletal framework of the face and occurs as a result of several factors.

Skin

Several processes related to ageing affect the appearance of the facial skin.

- Epidermal and dermal atrophy – results in wrinkling and thinning of the skin.
- Loss of skin elasticity – water content reduces and collagen synthesis declines, leading to sagging of the skin.
- Degradation of skin quality and colour.
- Wrinkling and furrowing of the skin overlying the facial muscles.

Note

The surface of the skin shows various linear grooves, some of which are always present but deepen with age, and others that appear in later life.

Skin contour lines are lines of division at junctions of various facial units, e.g. the nasolabial groove. These tend to deepen and thus appear more prominent with age.

Wrinkle lines, or facial expression lines, are caused by contraction of underlying muscles and are usually perpendicular to their axis of contraction, e.g. horizontal forehead creases. With progressive loss of skin elasticity due to ageing, these lines may become permanent.

Dependency lines are produced by the effect of gravity on loose skin or subcutaneous fatty tissue, e.g. the creases formed anterior and inferior to jowls.

Relaxed skin tension lines (RSTLs) are those that follow the furrows formed when the skin is *relaxed*;³⁷ for the most part they correspond to wrinkle lines, except on the lateral aspect of the nose, lateral aspect of the orbit and the chin. As such, RSTLs may act as a guide in planning elective facial incisions – closure of an incision in a straight line, with its long axis parallel to the natural RSTLs, may permit the resultant scar to appear as a natural skin crease (Figure 8.27).

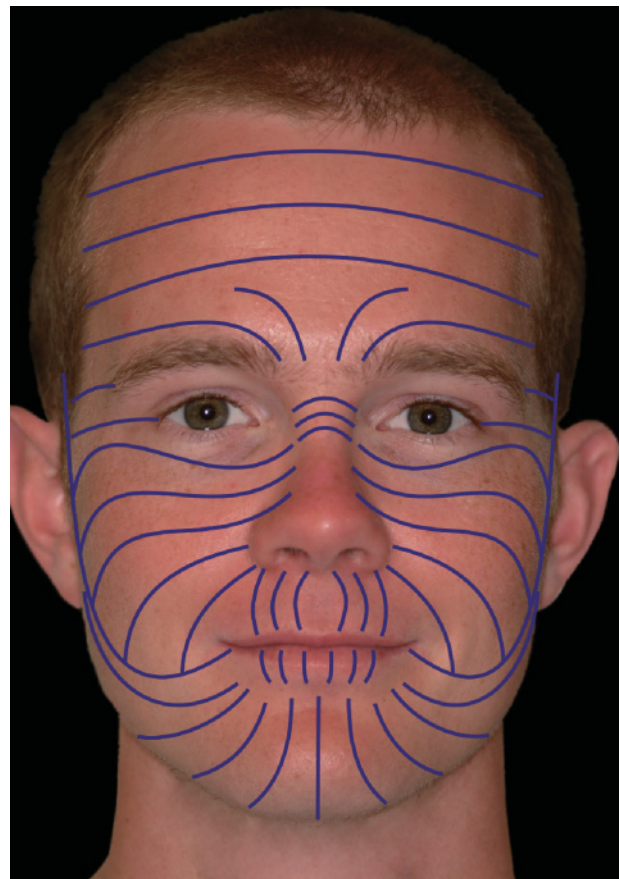


Figure 8.27 Relaxed skin tension lines.



Figure 8.28 Excessive subcutaneous fat accumulation and skin laxity.

Fat

The processes occurring in adipose tissue that affect the appearance of the facial skin with age are:

- Atrophy of the uniformly distributed subcutaneous fat.
- Localized, excessive subcutaneous fat accumulation (Figure 8.28).

Muscle

The reduced tonicity of the muscles of facial expression with age affects the appearance of the facial skin.

Dentoalveolus

With regard to the dentoalveolus, alveolar bone resorption in edentulous patients has a significant affect on facial appearance. The alveolar bone supports the teeth, and tooth loss leads to *progressive* loss of alveolar bone; the mandible thereby rotates forward, increasing chin prominence and reducing the lower anterior face height, with the chin moving towards the nose (Figure 8.29). The loss of dentoalveolar support also results in bilabial retrusion and a 'dished-in' appearance (Figure 8.30).

Recognizing the visible effects of ageing

Patient's should be examined in NHP, in a brightly lit room. There is progressive descent of the facial soft tissues with ageing, which may lead to the facial changes listed in the legend of Figure 8.31.

Ptosis of the forehead may be accompanied by horizontal forehead creases and vertical glabellar frown lines (due to

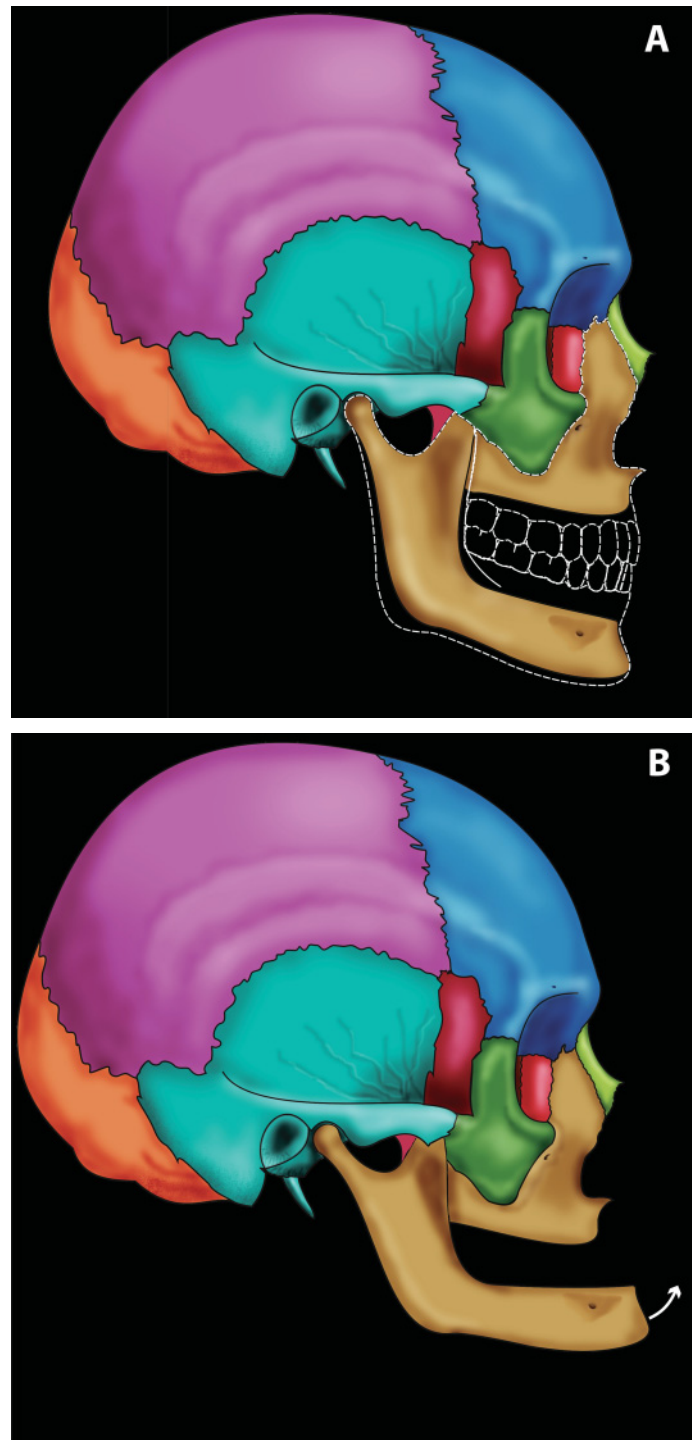


Figure 8.29 (A) Changes to the maxilla and mandible resulting from alveolar bone resorption and ageing. (B) Forward and upward mandibular rotation increases chin prominence and reduces the lower anterior face height.

contraction of the corrugator muscles). Ageing of the orbital region is characterized by excessive, redundant skin in the eyelids, lowering of the brow and orbital 'hooding', descent of the lateral canthus and bulging of orbital fat. The eyebrows sag to below the brow ridge.



Figure 8.30 Facial profile changes associated with ageing and resulting from tooth and alveolar bone loss (*Old and young man facing each other*, Leonardo da Vinci, c. 1495, Uffizi Gallery, Florence).

Midfacial soft tissues sag, resulting in exposure of the inferior orbital rim, deepening of the nasolabial folds and jowl formation. The nasal tip descends. Neck skin laxity and excess leads to hanging skin folds. Submental-cervical fat accumulation, platysmal banding and descent of the submandibular gland amplify the aged appearance of the neck region (Figure 8.32).



Figure 8.32 The ageing neck.

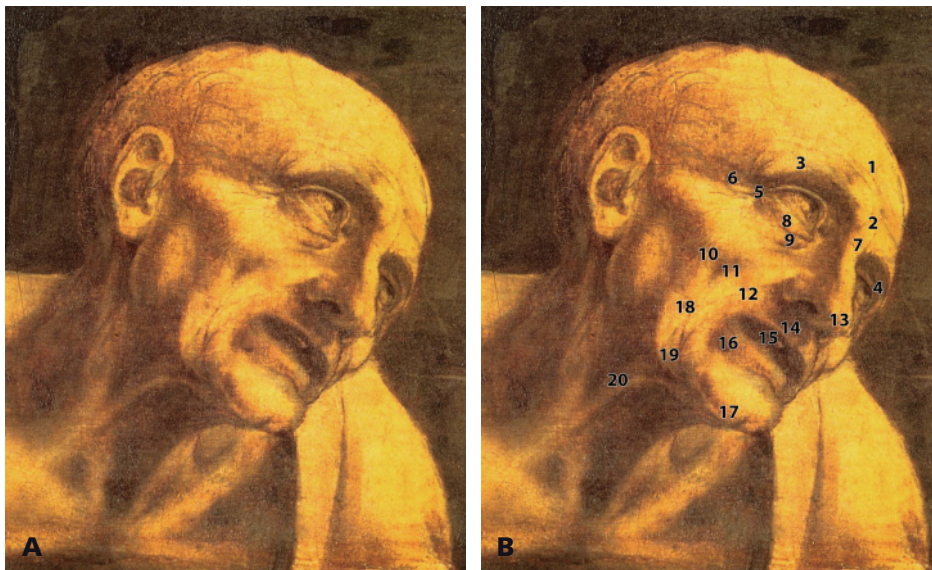


Figure 8.31 (A) *St Jerome* (c. 1480, Leonardo da Vinci. Pinacoteca Vaticana, Vatican City). (B) Typical facial ageing changes:

- | | | |
|--|------------------------------------|-------------------------------|
| 1 Forehead rhytids ('forehead creases') | 8 Lower eyelid ptosis | 15 Vermilion thinning |
| 2 Glabellar rhytids ('frown lines') | 9 Lower lid fat pseudoherniation | 16 Perioral rhytids |
| 3 Brow ptosis | 10 Cheek rhytids | 17 Chin ptosis |
| 4 Upper eyelid ptosis | 11 Cheek fat atrophy | 18 Facial sagging and rhytids |
| 5 Lateral canthal ptosis | 12 Deepened nasolabial fold | 19 Jowls |
| 6 Crow's feet wrinkles | 13 Nasal tip ptosis and dependency | 20 Platysmal bands |
| 7 Nasal radix rhytids (layperson term 'bunny lines') | 14 Upper lip sag | |

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Chapter 9 Facial Proportions

Introduction

‘... never depart from the guiding line of proportion. Harmony or disharmony does not lie within angles, distances, lines, surfaces or volumes. They arise from proportion.’

Dr Paul Tessier (1917–2008),¹ French surgeon and acknowledged father of modern craniofacial surgery

Proportion may be defined as the ideal, attractive relationship between one part to another or between the parts of a whole (Latin *proportionem*: ‘comparative relationship’). There is no absolute correlation between a well-proportioned face and facial beauty. In the essay ‘Of Beauty’ (1625), Sir Francis Bacon wrote: ‘There is no excellent beauty that hath not some strangeness in the proportion.’² However, a well-proportioned face will be acceptable, even if not always beautiful. In the sixteenth century, Albrecht Dürer explained that although the concept of facial beauty was immersed in subjectivity, the assessment of facial proportions could be undertaken objectively.³ He maintained that disproportionate human faces were unattractive (Figure 9.1), whereas proportionate features were acceptable, even if not always beautiful (Figure 9.2). Therefore, the *appropriate aim of objective clinical examination is the detection of facial disproportions*.

Individuals may vary quite considerably from population norms, but by understanding average proportions the clinician will be able to detect where the differences occur. By evaluating overall facial proportions, followed by the proportion of each respective facial part to the whole craniofacial complex, the

Note

The concept of physical beauty has been correlated with harmonious proportions throughout history. The notion is that the proportionate human face and figure is the most aesthetically pleasing. With this idea arises the question of what are ideal proportions and how does one test and validate them?

The perception of ideal proportions may vary from one individual to another, from one ethnic group to another and from one historical era to another. It is therefore vital for clinicians involved in the management of patients requiring alterations in their facial appearance to have an evidence-based approach to the guidelines they employ in planning the correction of facial disproportions.

The sources for the proportional relationships currently used in clinical practice have been discussed in Chapter 2. Such evidence may be obtained from three sources:

- **Art and sculpture:** ‘Ideal’ facial proportions may be derived from classical, Renaissance and neoclassical art and sculpture.
- **Anthropometry:** Age-, sex- and ethnicity-specific ‘normal’ or ‘average’ facial proportions, together with acceptable ranges of normal variability, are derived from **anthropometric** and **cephalometric** data from **population samples**. Such data may be used to obtain age-, sex- and ethnicity-specific population averages for the various proportional canons or guidelines being tested.
- **Attractiveness studies:** Both the above sources may be tested with attractiveness studies, providing confirmation of the perceived attractiveness of any facial parameter by the judgement of the lay public and clinicians.

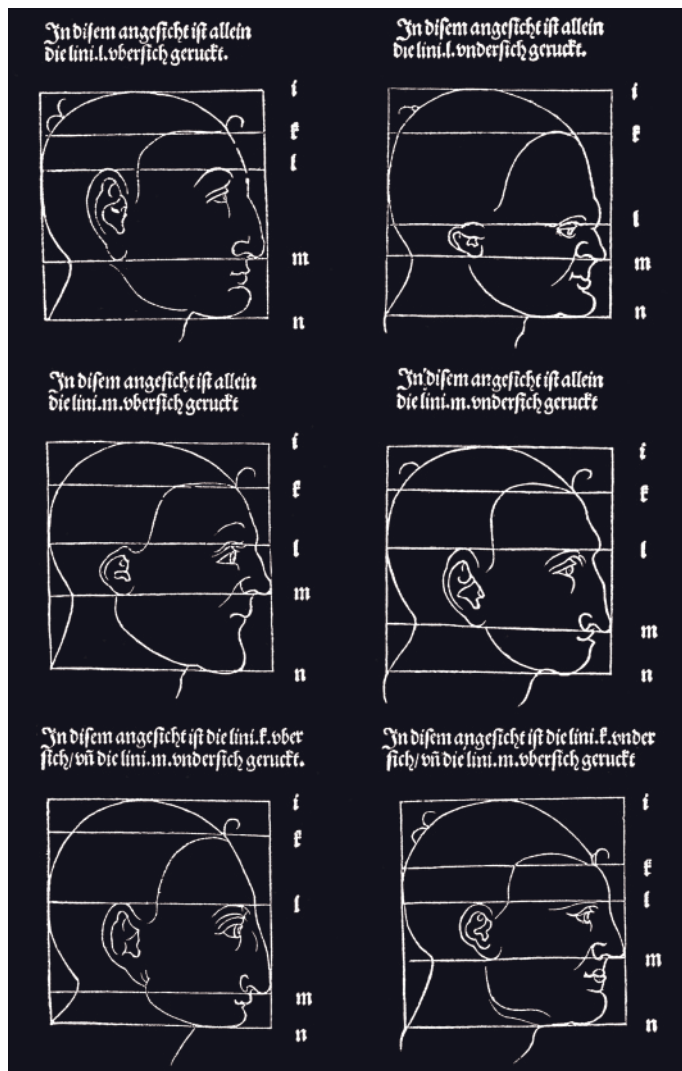


Figure 9.1 Vertical facial disproportions. (Redrawn from Dürer.⁴)

clinician will be able to detect both the source(s) of the disproportional face and the degree of variance from the acceptable norm.

Note

The skull may be divided into two main regions – the **neurocranium** (cranial vault and cranial base) and the **viscerocranium** (facial skeleton). Postnatal growth of the cranium is largely completed by 7–8 years of age, whereas facial growth continues well into the second decade of life, much of which is related to the development of the teeth. Therefore, the relative sizes of the cranial vault and facial skeleton in the neonate and the adult are very different, with the adult face constituting a much larger proportion of the overall craniofacial complex (Figures 9.3 and 9.4).

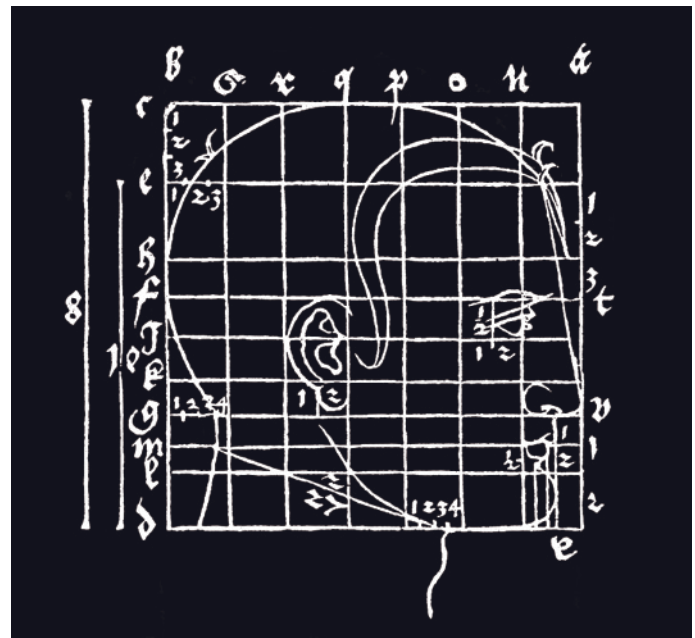


Figure 9.2 Ideal craniofacial proportional relationships. (Redrawn from Dürer.⁴)

As always in clinical examination, it is important not to ‘miss the wood for the trees’. Clinical evaluation must begin with overall craniofacial proportional relationships and gradually work towards more detailed analysis.

Craniofacial height to standing height proportion

A useful starting point for the clinical evaluation of craniofacial proportional relationships, which may be potentially significant in treatment planning, is that of the craniofacial height to standing height proportion.⁵

Note

It is important to bear in mind that the proportional relationship between head size and body size varies throughout growth, with *relative* head size decreasing significantly until the late teenage years (Figure 9.5).⁶ This pattern of growth is termed **allometric growth**, which describes the differences in the relative rates of growth between one part of the body and another. At birth, neonatal craniofacial height is approximately one-quarter of body height, but in the young adult this proportion is halved to approximately an eighth.

Classical, Renaissance and neoclassical proportional canons

The first significant known study of human proportions was undertaken in the fifth century BC by the Greek sculptor

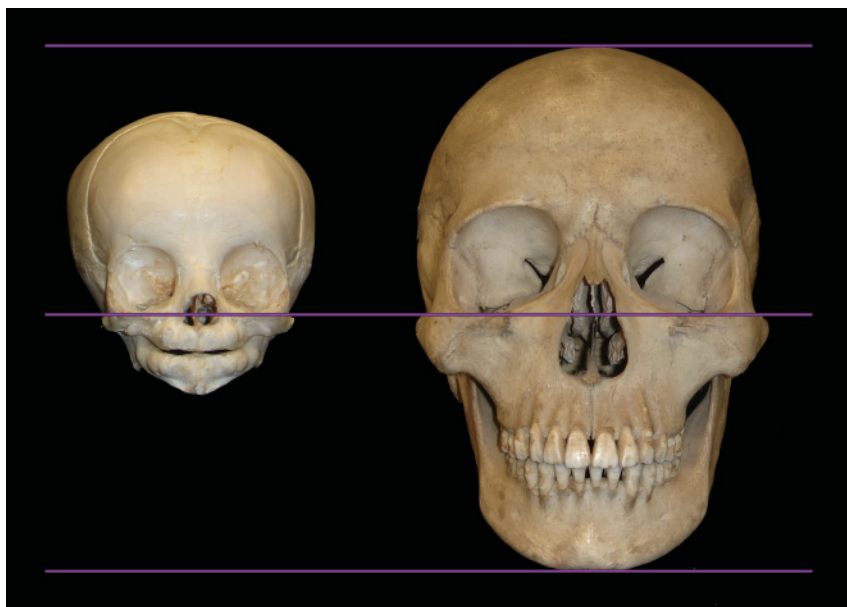


Figure 9.3 Proportional differences in the size of the neonatal and adult skull. In the neonate, the face and jaws are relatively underdeveloped in comparison with the adult.

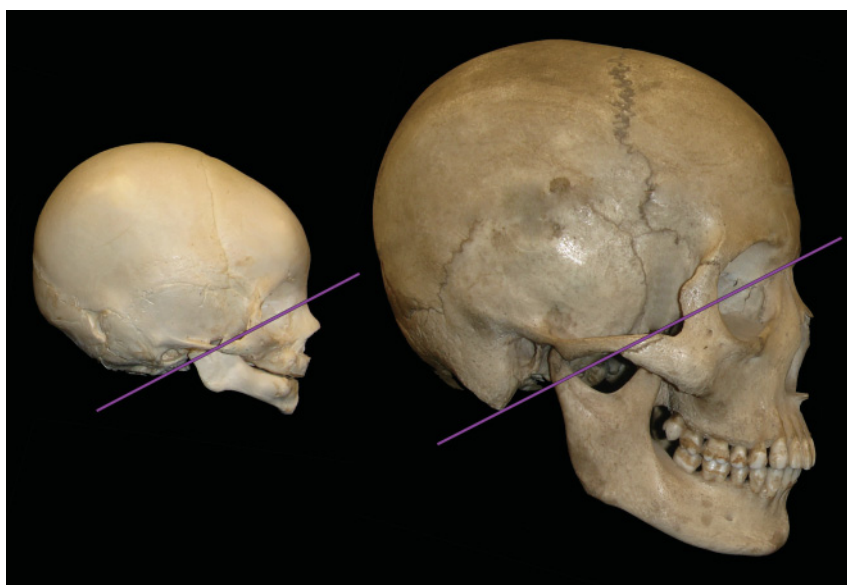


Figure 9.4 Relative sizes of the cranium and facial skeleton in the neonatal and adult skull. The extent of postnatal growth of the face and, in particular, the jaws exceeds that of the cranial structures.



Figure 9.5 Schematic representation of the changing proportions of head size to body size during normal growth and development. (Redrawn from Medawar and Le Gros⁶ with permission from Oxford University Press.)

Polycleitos, of Argos. It is generally acknowledged that the work of Polycleitos was used by other sculptors as demonstrating the 'ideal' proportions of a man. The *Canon* of Polycleitos refers to both the book written by Polycleitos, of which no copies exist, and the Roman marble copies of his original bronze statue described as the *Canon*, otherwise known as the *Doryphoros* ('Spear-bearer') (Figure 9.6). Therefore, the 'ideal' human proportions suggested by Polycleitos may only be gleaned from examination of Roman copies of the *Doryphoros*.⁷ The cranio-

facial height to standing height proportion of the available marble copies of the *Doryphoros* is $\frac{1}{7.5}$.

In the late fourth century BC, the prolific Greek sculptor **Lysippos** (c. 330 BC) is thought to have revised the canon of Polycleitos, establishing a new canon in the use of eight heads to standing height. This is evident from inspection of the Roman marble copy of the *Apoxyomenos* ('The Scraper', depicting an athlete scraping off olive oil from his body, commonly undertaken following sporting activities in ancient Greece) (Figure 9.7); it is



Figure 9.6 *Doryphoros* ('Spear-bearer'). In the fifth century BC, Polycleitos wrote the *Canon*, in which he laid down the guidelines for the ideal proportions of the human body. In this statue, also often referred to as the *Canon*, Polycleitos created the archetype of the Greek ideal of male beauty. (Roman copy after the Greek original; Naples Museum.)

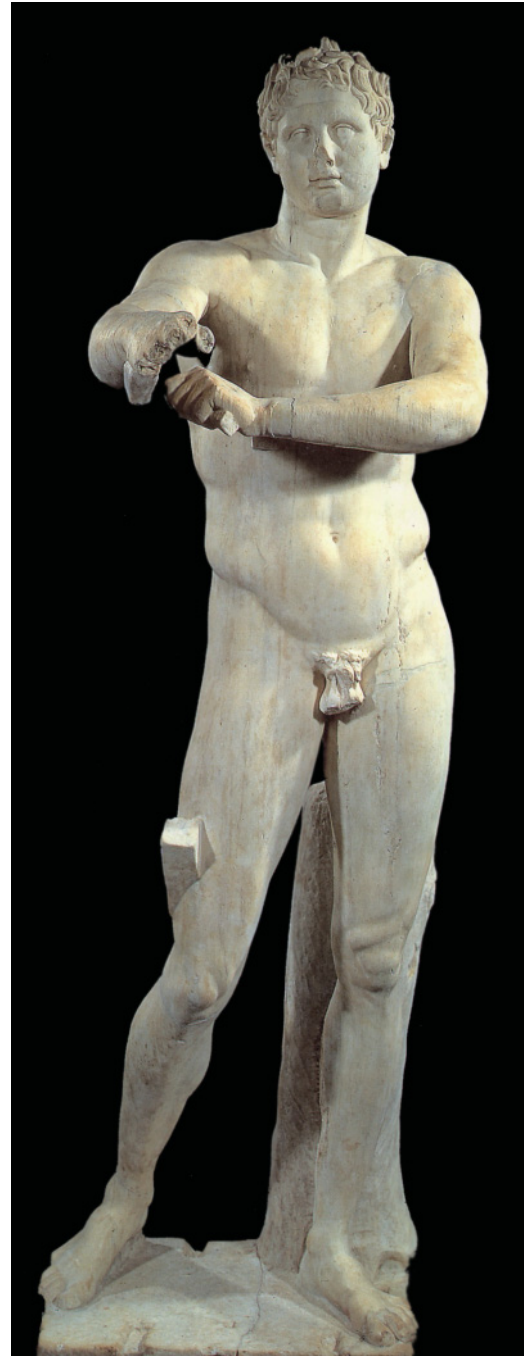


Figure 9.7 *Apoxyomenos* ('The Scraper') of Lysippos. (Roman copy after the Greek original; Vatican Museum.)



Figure 9.8 *Apollo Belvedere* of Leochares. (Roman copy after the Greek original; Vatican Museum.)

also evident in the famous statue by the Greek sculptor **Leochares** (a contemporary of Lysippos), the *Apollo Belvedere*, in the Vatican Museum (Figure 9.8).

The Roman architect Marcus Vitruvius Pollio, better known simply as **Vitruvius**, lived in the first century BC, and is thought to have dedicated his ten-volume treatise *De Architectura* ('On Architecture') to the emperor Augustus Caesar in about 25 BC. In the first chapter of Book III, entitled 'On symmetry in temples and the human body', he defined proportion as 'a correspondence among the measures of the members of an entire work, and of the whole to a certain part selected as standard.'⁸ Vitruvius believed that Nature's designs were based on universal laws of proportion and therefore that the human body's proportions could be used as a model of natural proportional perfection. He described how ancient artists and sculptors, particularly the Greeks, had examined many examples of 'well-shaped men' and

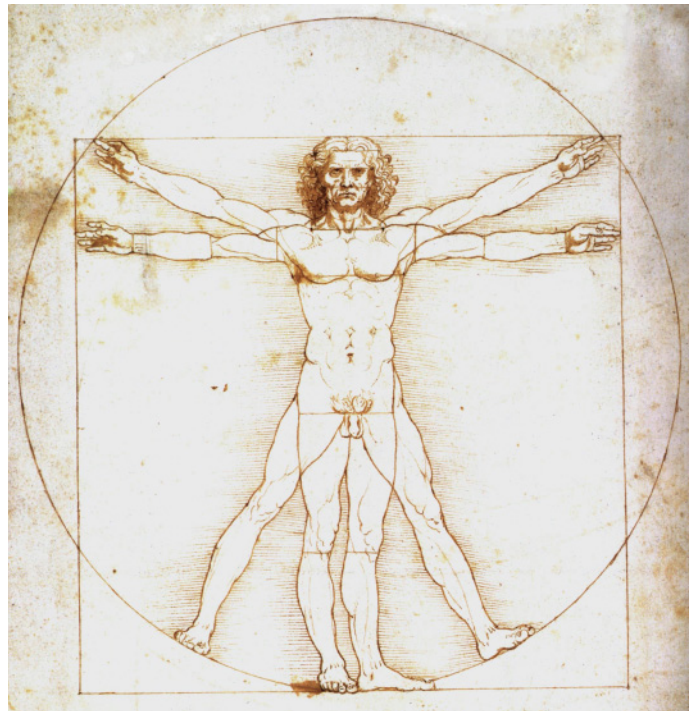


Figure 9.9 Leonardo da Vinci's *Vitruvian Man* (*Homo vitruvianus*) (c. 1490). This famous figure shows that the proportionate human form fits perfectly in perfect geometric shapes, the circle and the square. The navel forms the centre. It is based on the 'ideal' male proportions described by the Roman architect Vitruvius. (Gallerie dell'Accademia, Venice.)

discovered that their bodies shared certain proportions. Hence, *it seems that anthropometry was used by the Greeks in attempting to determine 'ideal' human proportional relationships*. Vitruvius wrote that 'the human body is so designed by nature that the face, from the chin to the top of the forehead and the lowest roots of the hair, is a tenth part of the whole height.'^{5,8} The facial height to standing height proportion of $\frac{1}{10}$ corresponds to a craniofacial height to standing height proportion of $\frac{1}{8}$.⁵

The scientifically enquiring minds of the Renaissance were no longer interested in blindly following the classical 'ideal', and began to study human anatomy and record human proportions. Adapting the work of Vitruvius with his own anthropometric research, the great Renaissance artist and thinker **Leonardo da Vinci** (1452–1519) provided the Renaissance canons of proportion. He described the 'ideal' craniofacial height to standing height proportion as $\frac{1}{8}$.⁹ In the late fifteenth century Leonardo drew the figure of *Vitruvian Man* (Figure 9.9), based on guidelines described by Vitruvius and his own anthropometric research, demonstrating the importance of proportions in the human form. He demonstrated that the 'ideal' human body fitted precisely into both a circle and a square, thus illustrating the link that he believed existed between perfect geometrical forms and the perfect body. The distance from the hairline to the inferior aspect of the chin is described as $\frac{1}{10}$ of a man's height. The distance from the top of the head to the inferior aspect of the chin is $\frac{1}{8}$ of a man's height.^{9,10}

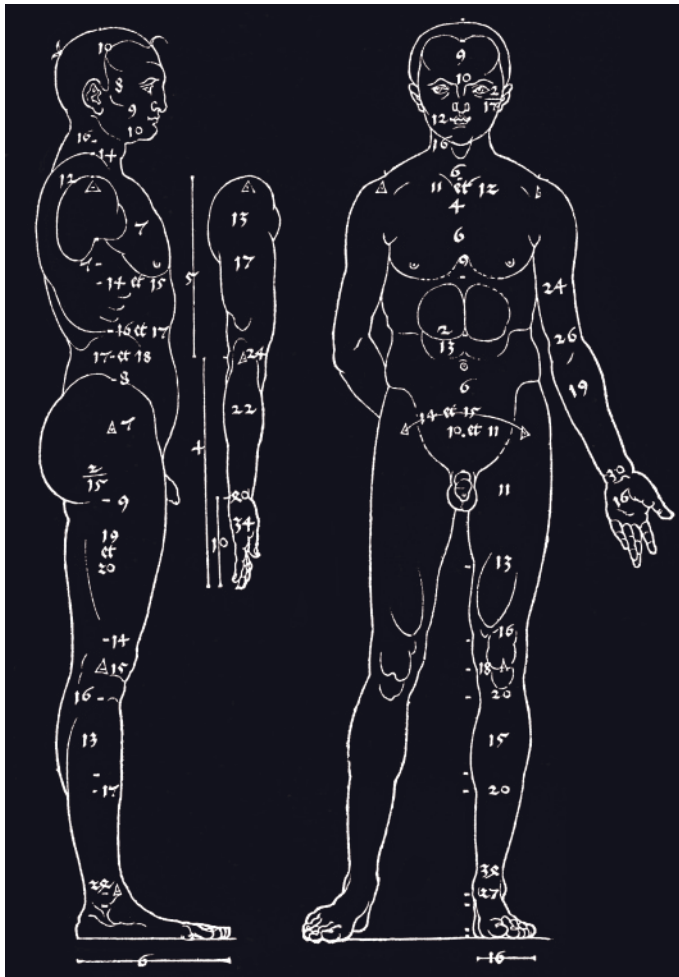


Figure 9.10 Albrecht Dürer's Man of Eight Head-Lengths. (Redrawn from Dürer.⁴)

Albrecht Dürer (1471–1528), perhaps the most significant artist of the German Renaissance, wrote a treatise on human proportions. The first of the *Four Books on Human Proportion*, published posthumously, described the 'ideal' man of *Eight Head-Lengths* (Figure 9.10).⁴ However, Dürer described the craniofacial height as ranging from $\frac{1}{7}$ to $\frac{1}{10}$ of standing height depending on the individuals' stature; the thinner the individual the closer to $\frac{1}{10}$ the proportion (Figure 9.11).

Anthropometric data

In the twentieth, and extending into the twenty-first, century **Leslie Farkas** undertook a large body of research into the anthropometry of the human head, providing anthropometric data for adult North American Caucasian and other ethnic group norms.¹¹

The craniofacial height to standing height proportion may be calculated from the original anthropometric data provided by Farkas et al.¹² From these original anthropometric data, the craniofacial height to standing height proportion in young adult males (age range 19–25 years) is $\frac{1}{7.7}$ (range $\frac{1}{7.4}$ to $\frac{1}{8.1}$), and in young adult females (age range 19–25 years) is $\frac{1}{7.6}$ (range $\frac{1}{7.2}$ to $\frac{1}{7.9}$).⁵

Attractiveness research

A study was undertaken to test the validity of the classical, neo-classical and modern anthropometric-based proportional canons for the craniofacial height to standing height proportion, and to compare the results with the judgement of perceived attractiveness of the lay public and clinicians.⁵ The results of the attractiveness study lend support to both the classical ideal of $\frac{1}{7.5}$ and the Renaissance ideal of $\frac{1}{8}$. The results of this study, based on layperson and clinician perceived judgements of

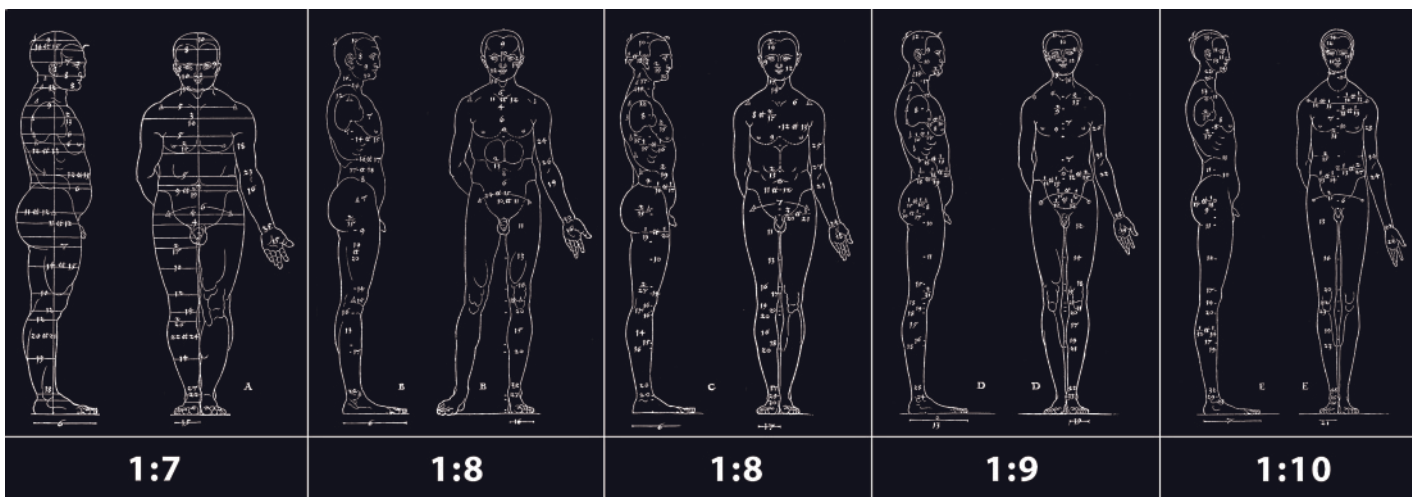


Figure 9.11 Dürer described the craniofacial height as ranging from one-seventh to one-tenth of standing height depending on an individual's stature; the thinner the individual the closer to one-tenth is the proportion. He considered types B and C (one-eighth proportional ratio) as closer approximations to the 'ideal.' The figures were based on anthropometric data collected by the measurement of 'many individuals' and coordinated into 'types'. (Redrawn from Dürer.⁴)

attractiveness, generally validate the anthropometric data. In this study it was found that a proportion of $\frac{1}{7.5}$ was perceived as the most attractive, with $\frac{1}{8}$ a close second. The images regarded as most attractive by the participants had a mean craniofacial height to standing height proportion of $\frac{1}{7.8}$ (minimum = $\frac{1}{7}$ and maximum = $\frac{1}{8.5}$). In addition, the mean rank preference score was found to be minimal for a craniofacial height to standing height proportion of $\frac{1}{8}$ and increased when the craniofacial height to standing height proportion moved away from $\frac{1}{8}$ in either direction. The ranking of the images was not influenced by the observer's age, sex, ethnicity or professional status, providing support to the available evidence for the universality of judgements of attractiveness.¹³

Clinical implications

Patients presenting with craniofacial or dentofacial anomalies are, by definition, not average. Therefore in treatment planning, the use of mean craniofacial measurements based on population norms, though extremely important, must be used in conjunction with, and guided by a thorough understanding of facial proportional relationships.

The proportion of vertical craniofacial (head) height, and vertical facial height, to standing height has important clinical implications. If the vertical craniofacial proportions of a patient are to be altered with surgery, the treatment plan must take into account the proportion of the patient's total face height to their standing height. The use of absolute numerical values of facial measurements rather than facial proportions may be misleading, as the vertical facial height of a patient who is 1.8 m (6 ft) tall will be different from that of a patient who is 1.5 m (5 ft) tall.⁷

It is recommended that in planning treatment to alter any aspect of craniofacial or facial height, the ideal craniofacial height to standing height proportion of $\frac{1}{7.5}$ – $\frac{1}{8}$, with a range from $\frac{1}{7}$ to $\frac{1}{8.5}$, be considered.⁵

Vertical facial proportions

Classical, Renaissance and neoclassical facial canons describe vertical proportional relationships with the **vertical craniofacial bisection**, the **vertical facial trisection** and the **vertical craniofacial tetrisection**.

Vertical craniofacial bisection (Figure 9.12)

The head may be vertically divided into halves, with the eyes positioned on a line constructed halfway between the top of the head (vertex) and the inferior aspect of the chin (soft tissue menton). The lower facial third may be further subdivided into two equal parts:

- Subnasale to labrale inferioris (or sublabiale).
- Labrale inferioris to menton.

Vertical facial trisection (Vitruvian trisection)

This proportional canon was described by the Roman architect Vitruvius and popularized by Leonardo da Vinci (Figure 9.13); the face may be vertically divided into thirds (Figure 9.14):

- Upper facial third: trichion (hairline) to glabella.
- Middle facial third: glabella to subnasale.
- Lower facial third: subnasale to soft tissue menton.

Note

In patients with **receding hairlines**, trichion may be located by instructing the patient to raise their eyebrows. The superior aspect of the contraction of the frontalis muscle indicates the position of trichion (Figure 6.18).

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Figure 9.12 Craniofacial bisection (modified, detail from Leonardo da Vinci's *Proportions of the Head and Human Figure*, c. 1490; Royal Library, Windsor Collection). (With kind permission from The Royal Collection © 2010 Her Majesty Queen Elizabeth II.)

The lower facial third may be further subdivided into thirds:

- Upper lip ($\frac{1}{3}$): subnasale to stomion (lip embrasure).
- Lower lip ($\frac{1}{3}$): stomion to mentolabial sulcus.
- Chin ($\frac{1}{3}$): mentolabial sulcus to menton.



Figure 9.13 Facial (Vitruvian) trisection (detail from Leonardo da Vinci's *Vitruvian Man*, c. 1490); though Leonardo describes the Vitruvian trisection in the text, the upper facial third is drawn slightly reduced in height compared with the middle and lower thirds.

Vertical craniofacial tetrasection (Figure 9.15)

This proportional canon was described by Albrecht Dürer; the head may be vertically divided into quarters:

- Upper quarter: vertex to trichion.
- Forehead: trichion to glabella.
- Upper face: glabella to subnasale.
- Lower face: subnasale to menton.

Artist's facial 'grid' (Figure 9.16)

A facial grid may be constructed using horizontal and vertical guidelines. The eyes sit on a line equidistant from vertex to menton. The grid is five eye widths wide and seven eye widths in height.

Validity of proportional canons

The canons described above were introduced by artists and sculptors as 'ideals' of beauty, which were depicted in sculpture and painting. They continue to be useful guidelines, yet they are *only guidelines*. Farkas et al.¹⁴ tested the validity of these canons in a healthy population of young adult white Caucasians ($n = 103$), and his findings are summarized below.

Craniofacial bisection

- Only 10% fitted the canon.
- In 80% the upper half was on average 12 mm taller (range 2–29 mm).
- In 10% the lower half was on average 6 mm taller (range: 4–9 mm).

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Figure 9.14 Facial trisection (modified, detail from Leonardo da Vinci's *Proportions of the Head and Human Figure*, c. 1490; Royal Library, Windsor Collection). (With kind permission from The Royal Collection © 2010 Her Majesty Queen Elizabeth II).

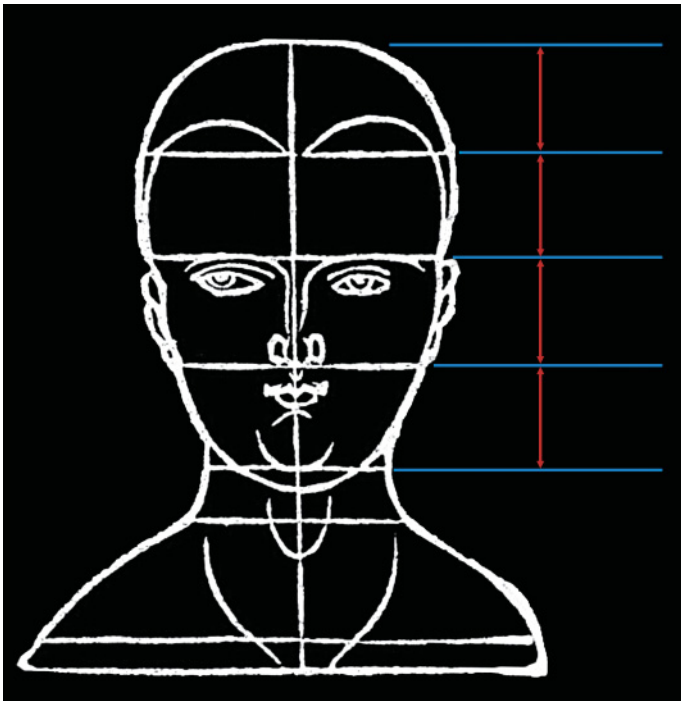


Figure 9.15 Vertical craniofacial tetrasedition. (Redrawn from Dürer.⁴)

Facial trisection

- None of the subjects fitted the canon.
- In 100% the lower anterior face height (subnasale-menton) was on average 18mm (range: 3–42mm) greater than the upper face height (trichion-glabella).
- In 68% the lower anterior face height (subnasale-menton) was on average 9mm (range: 2–21mm) greater than the midfacial height (glabella-subnasale).

Craniofacial tetrasedition

- None of the subjects fitted the canon.
- In 100% the lower anterior face height (subnasale-menton) was on average 19mm (range: 2–42mm) greater than the upper head height (vertex-trichion).
- In 87% the middle anterior face height (glabella-subnasale) was on average 15mm (range: 2–37mm) greater than the upper head height (vertex-trichion).

Cephalometric evaluation – anterior face height ratio (Figure 7.45)

To evaluate the proportional relationship of the lower to the middle anterior face height, horizontal lines are projected from N, ANS and Me onto the true vertical. The middle anterior face height (MAFH) is measured from the projection of N to that of ANS. The lower anterior face height (LAFH) is measured from the projection of ANS to that of Me. The proportional

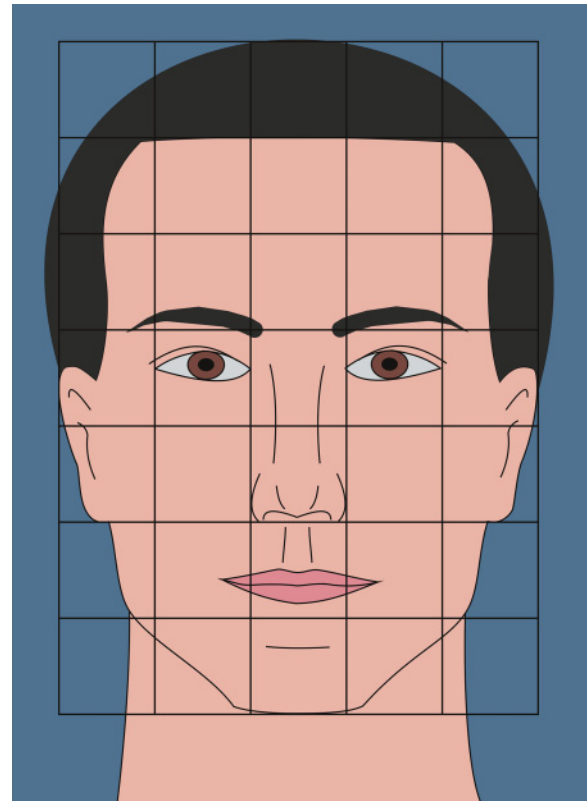


Figure 9.16 The artist's grid describes the face as five eye widths wide and seven eye widths in height.

relationship of MAFH:LAFH is approximately 45:55%. This proportional relationship is more important than any absolute measurements.

Lower anterior facial proportions

Leonardo da Vinci (c. 1490) subdivided the lower anterior face height into thirds, with the upper lip height $\frac{1}{3}$ and the lower lip and chin height as $\frac{2}{3}$; this proportional relationship was subsequently confirmed in contemporary cephalometric studies by Worms et al.¹⁵ and Legan and Burstone.¹⁶

Albrecht Dürer (1528) subdivided the lower anterior face height into quarters, with the upper lip height $\frac{1}{4}$ of lower facial height.⁴

Scheideman et al.¹⁷ found:

- LAFH to be equal to the MAFH in women.
- LAFH greater than MAFH in men, mainly due to a greater lower lip/chin height.

Farkas et al.¹⁸ found:

- Upper lip height ~31% of LAFH.
- Lower lip height ~26% of LAFH.
- Chin height ~43% of LAFH.

There is variation in the proportional canons and individual variability in the results of modern studies; this again demon-

strates that such relationships are a useful first step in the clinical evaluation of lower facial proportions, but only as *guidelines*. Each patient must be evaluated as an individual.

Anthropometric vertical facial measurements

When evaluating the vertical facial soft tissue proportions, it is useful to supplement the information from the proportional canons relationships with age-, sex- and ethnicity-specific anthropometric norms with normal ranges of variability for each vertical facial parameter (Table 9.1). Using such normative values permits the derivation of **modern measured proportional ratios** for specific patient groups.¹⁴

Comparison of proportional canons with modern measured proportional ratios

The normative values provided by Farkas et al.,^{14,18} may be used to derive modern measured proportional ratios for white

Caucasian patients (Figures 9.17 and 9.18). Figures provided by Bhatia and Leighton (1993) from measurements of white Caucasian individuals in the UK are slightly different.¹⁹ Midfacial height and lower facial height were found to be equal in men (70 mm) and women (65 mm). The lower facial proportions were almost identical with the values provided by Farkas et al.¹⁸

Attractiveness studies

Johnston et al.²⁰ investigated the influence of changing the lower face vertical proportion using facial profile silhouettes, using attractiveness ratings scored by lay people. They found that the most attractive lower face proportion was the Eastman norm, i.e. LAFH was 55% of total anterior face height measured from nasion to menton. This corresponds to a MAFH:LAFH ratio of 50:50 if face height is measured from glabella. Images with a reduced lower face proportion were considered more attractive than corresponding images with an increased lower face proportion.

Table 9.1 Anthropometric vertical facial measurements

	Age (years)	Lower anterior face height (LAFH): subnasale – menton (mm)	Middle anterior face height (MAFH): glabella – subnasale (mm)	Upper anterior face height (UAFH): trichion – glabella (mm)	Total anterior face height (TAFH): trichion – menton (mm)
Male	12	65 (SD 5)	55	54 (SD 7)	174 (SD 9)
	18	72 (SD 5)	57	58 (SD 7)	187 (SD 8)
Female	12	65 (SD 4)	54	50 (SD 6)	169 (SD 7)
	18	66 (SD 5)	56	51 (SD 6)	173 (SD 8)

SD, standard deviation.
Figures are calculated and modified from original data by Farkas,¹² based on adult North American white Caucasian Norms. Middle anterior face height data not provided by Farkas,¹² therefore calculated: MAFH = TAFH – (LAFH + UAFH).

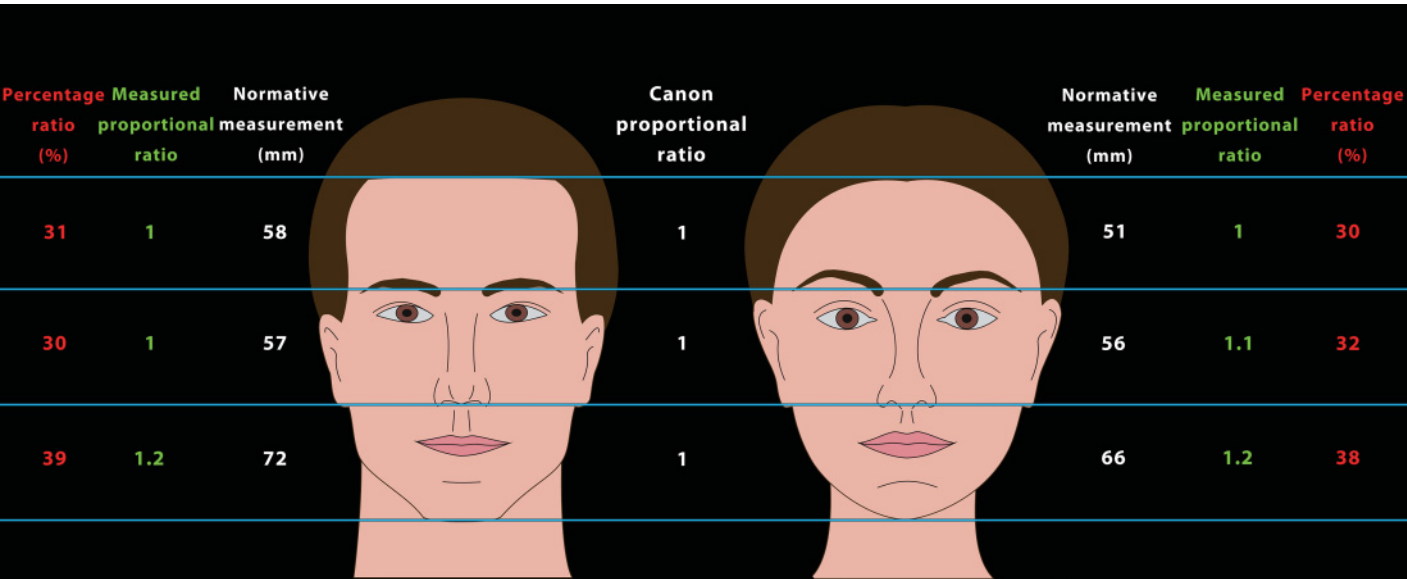


Figure 9.17 The facial trisection canon compared with proportional ratios derived from modern anthropometric measurements.

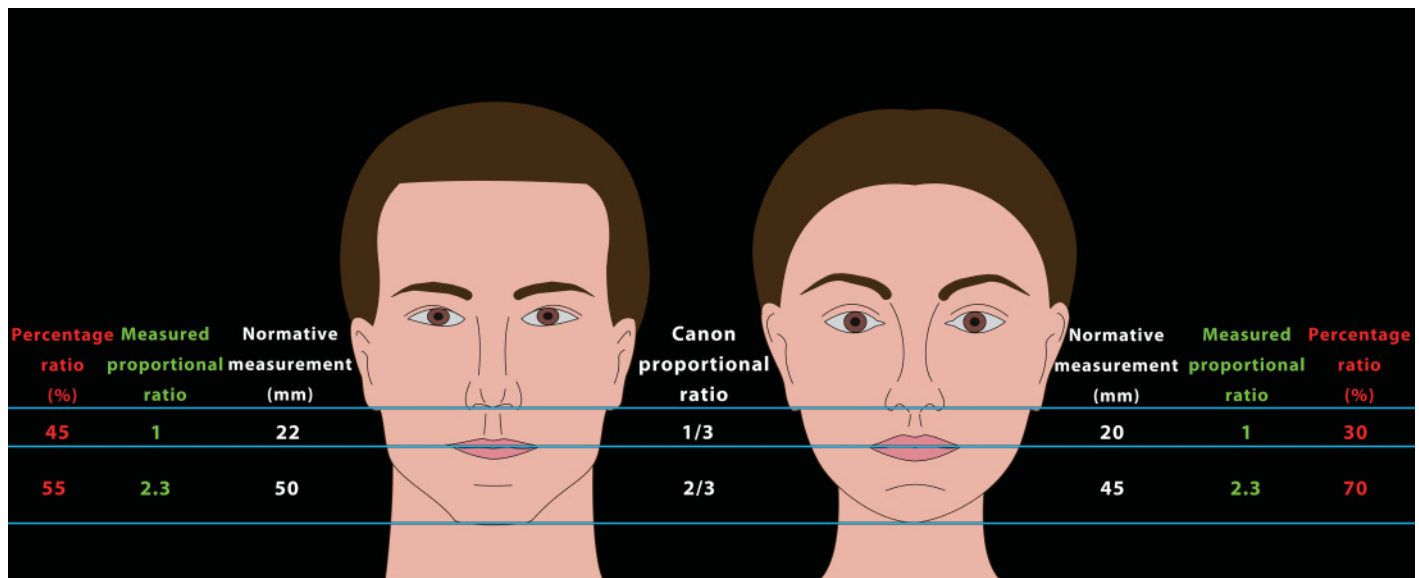


Figure 9.18 The lower facial height canon compared with proportional ratios derived from modern anthropometric measurements.

Clinical implications

Knowledge of vertical facial proportions is important in planning dentofacial surgery, as well as in any prosthodontic treatment plan aimed at altering the occlusal vertical dimension. The vertical facial thirds should be *approximately* equal, although the lower facial third may be slightly greater than the middle third, particularly in males. The lower facial third may be further subdivided, with the upper lip forming the upper third and the lower lip and chin forming the lower two-thirds. An increased lower anterior facial height may be due to:

- **Vertical maxillary excess (VME):** Total VME results from excessive inferior development of the maxilla (Figure 9.19). This is often accompanied by excessive maxillary incisor exposure in repose and excessive gingival display at rest and on smiling, sometimes referred to as a 'gummy smile'. Treatment, therefore, centres on superior repositioning of the maxilla. In certain cases **anterior VME** may be due to excessively over-erupted maxillary incisors and canines (for example, Class II division 1 or 2 malocclusion) (Figure 9.20), in which case the treatment of choice will either be an anterior segmental impaction of the maxilla, or orthodontic intrusion of the maxillary incisors and associated gingivae. A 'gummy smile' may also be due to excessive gingival tissue (Figure 9.21), in which case a gingivectomy to remove excess gingival tissue and thereby move the gingival margin apically would be the treatment of choice.
- **Increased vertical chin height:** The proportion of the lower two-thirds of the lower facial third (stomion to soft tissue menton) to the lower facial third (subnasale to soft tissue menton) will be increased (Figure 9.22). Treatment will therefore centre on vertical reduction genioplasty.

The height of the face must be assessed bearing in mind the patient's standing height and stature as already described. The distance from the hairline (trichion) to the inferior aspect of the chin (soft tissue menton) is approximately $\frac{1}{10}$ of standing height. The distance from the top of the head to soft tissue menton is approximately $\frac{1}{8}$ standing height.

Transverse facial proportions

The **rule of fifths** is a practical and convenient guideline used to analyse transverse facial proportional relationships. According to this rule, the 'ideal' face may be transversely divided into five equal parts, each roughly equal to one eye width (Figure 9.23).

The central fifth of the face

The central fifth of the face is delineated by the medial canthi of the eyes (Figure 9.24).

The **alar base width** should be roughly equal to the **intercanthal width**. This is important clinically as anterior and/or superior repositioning of the maxilla tends to increase the alar base width. This may be partially counteracted by placement of an 'alar cinch suture' at the time of surgery to maintain the alar base width.

The inherent ethnic variation in alar base width must be taken into account in diagnosis and treatment planning (Table 9.2).

An **increased intercanthal distance** may be due to (Figure 9.25):

- **Telecanthus** – a soft tissue measurement reflecting increased distance between the medial canthi of the eyelids. It is a common finding in patients with Down syndrome.
- **Orbital hypertelorism** – the increased distance between the medial orbital walls, reflecting an increased distance between

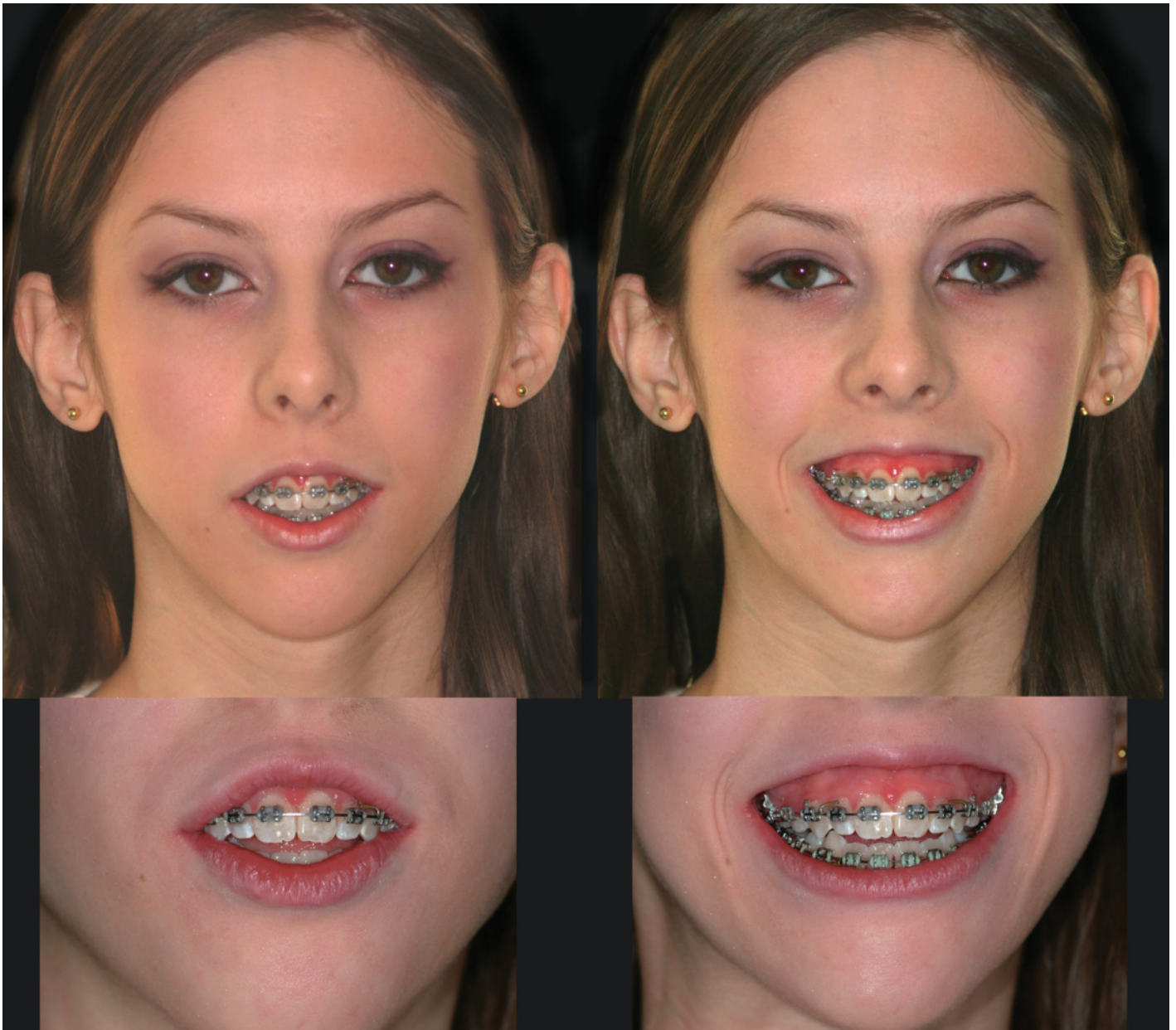


Figure 9.19 Total vertical maxillary excess. Excessive gingival exposure is evident anteriorly and posteriorly.



Figure 9.20 Anterior vertical maxillary excess. Excessive anterior dentogingival exposure resulting from overeruption of the maxillary incisor and canine teeth.



Figure 9.21 Excessive gingival tissue.

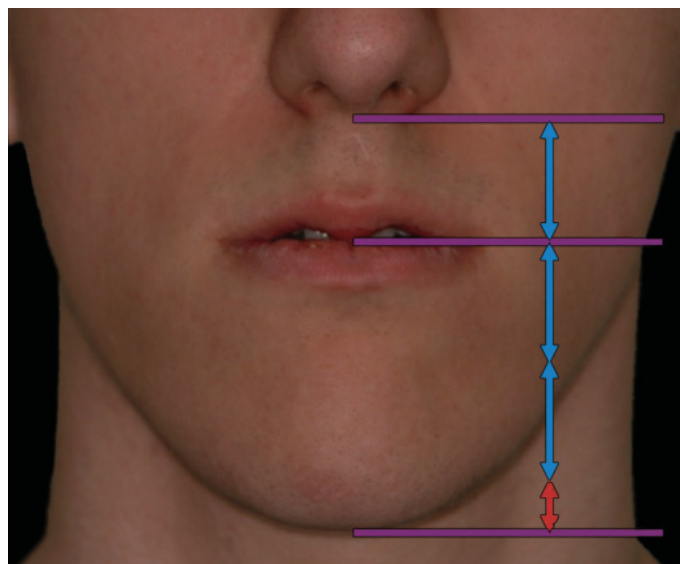


Figure 9.22 Vertical chin excess. Increased vertical chin height (stomion to soft tissue menton), leading to an increase in the lower anterior facial height.

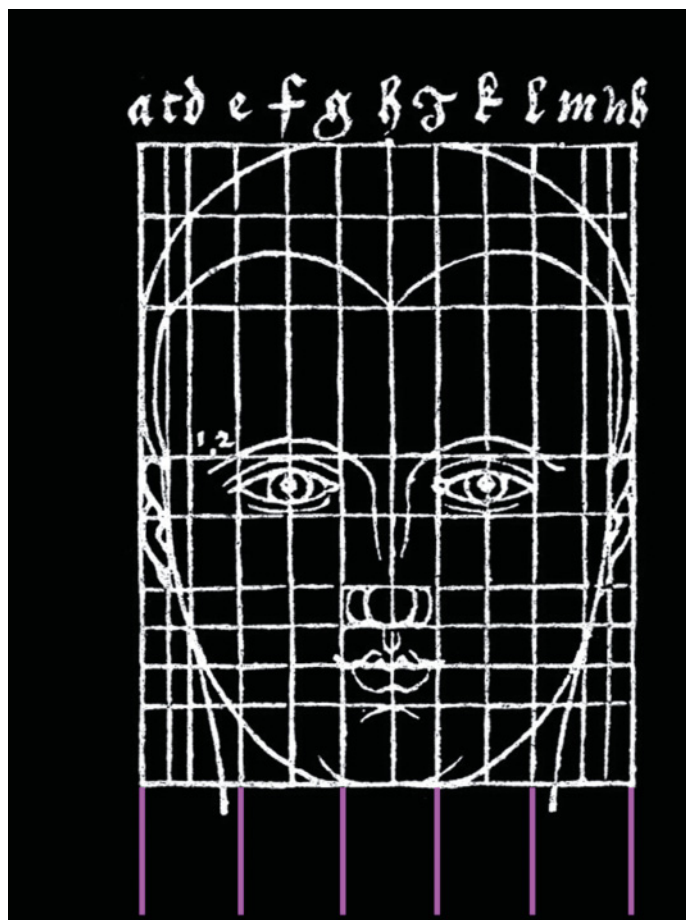


Figure 9.23 Rule of fifths. (Redrawn from Dürer.⁴)

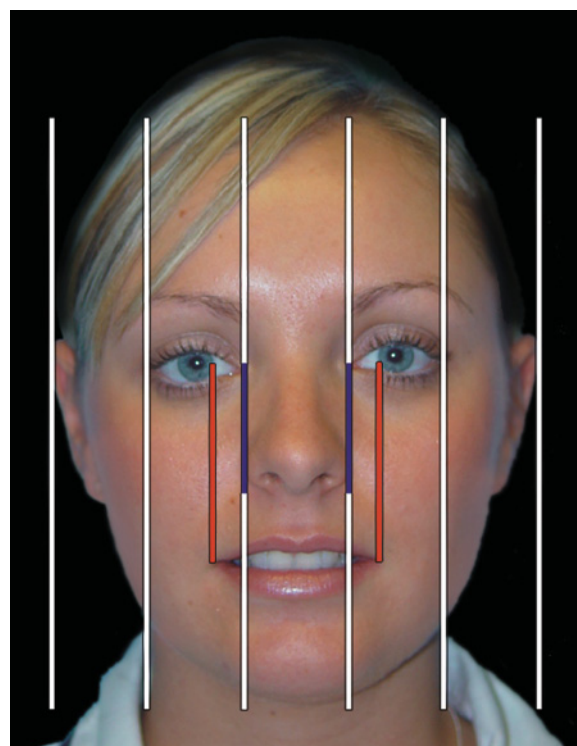


Figure 9.24 Transverse facial proportions. The 'rule of fifths' states that transverse facial dimensions may be divided into equal fifths, each the width of an eye. The nasal alar base width should be equal to the intercanthal distance. The mouth width is equal to the distance between the medial iris margins.

Table 9.2 Normative values in young adults (age 18) for intercanthal and nasal alar base widths in three ethnic groups

	White Caucasian		Chinese		Black	
	Intercanthal width (mm)	Alar base width (mm)	Intercanthal width (mm)	Alar base width (mm)	Intercanthal width (mm)	Alar base width (mm)
Male	33 (SD 3)	33 (SD 2)	38 (SD 3)	39 (SD 2)	36 (SD 3)	40.0 (SD 5)
Female	32 (SD 2)	31 (SD 2)	36.5 (SD 3)	36.5 (SD 2)	34 (SD 3)	38 (SD 4)

SD, standard deviation.
Data modified from Farkas.¹²

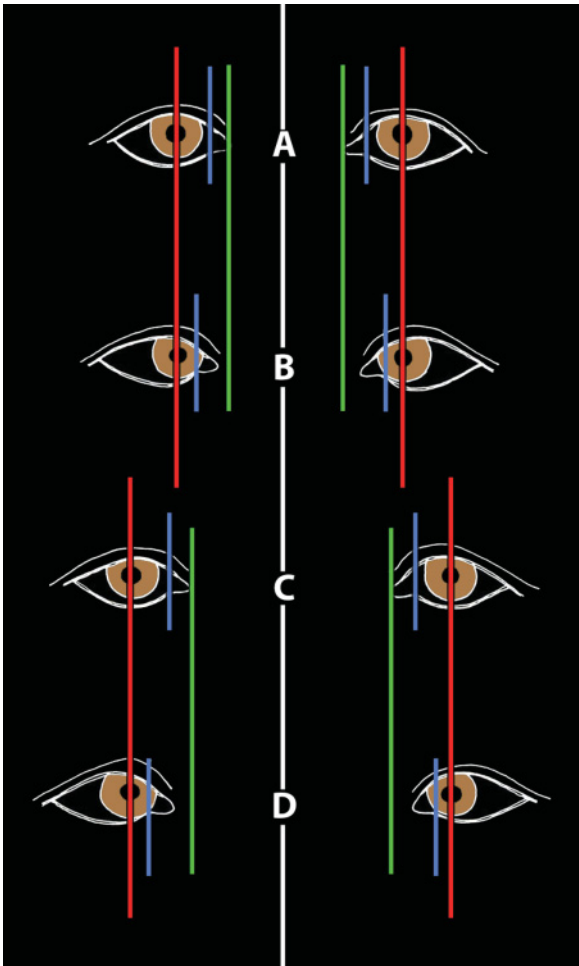


Figure 9.25 Telecanthus and hypertelorism. A: Normal interocular dimensions. B: Primary telecanthus: medial canthi are excessively separated, but lateral canthi normally spaced. C: True ocular hypertelorism: both medial and lateral canthi are abnormally far apart. D: True ocular hypertelorism and secondary telecanthus. Note that the vertical blue line through the lacrimal punctum cuts the cornea. (Redrawn from Cohen et al.²¹ with permission from Elsevier.)

the orbits (greater than two standard deviations from the norm). It is a common finding in a number of craniofacial malformations, such as Crouzon syndrome, Apert syndrome and Pfeiffer syndrome (Figure 9.26).²¹



Figure 9.26 Orbital hypertelorism in a patient with Crouzon syndrome.

The medial fifths of the face

The medial fifths of the face are measured from the lateral to the medial canthi of the eyes. **Mouth width** at rest is approximately equal to the distance between the medial iris margins (Figure 9.24). **Bigonial width** is slightly greater than biocular width (distance from the left to the right lateral canthus), i.e. the line from the lateral canthi of the eyes (outer border of the medial fifth of the face) should be approximately coincident with the antegonial region. Bigonial width should be approximately 70–75% of bizygomatic width.



Figure 9.27 Increased bigonial width.

Increased bigonial width may occur in patients with increased skeletal bigonial width, or in patients with masseter muscle hypertrophy; the gonial angles will be lateral to the outer border of the medial fifth of the face (Figure 9.27). Conversely, patients with reduced bigonial width may require gonial angle implants to correct this proportion.

The lateral fifths of the face

The lateral or outer fifth of the face is measured from the lateral canthus of the eye to the helix of the ear. Prominent ears may have a significant effect on facial aesthetics, particularly if they cannot be camouflaged by altering the hairstyle. Correction of laterally prominent ears may be undertaken by otoplasty (Chapter 13).

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Chapter 10 Facial Symmetry and Asymmetry

Introduction

Symmetry may be defined as correspondence in size, shape and relative position of parts on opposite sides of a dividing line or median plane. **Asymmetry** is defined as a lack or absence of symmetry. The application of this definition to the human face illustrates an imbalance or disproportionality between the right and left sides of the face. No human face exhibits perfect bilateral symmetry. Although a mild degree of asymmetry is normal and acceptable in the average face, greater degrees of asymmetry have been correlated with clinical depression, low self-esteem and other health problems associated with poor quality of life, such as neurosis and an inferiority complex.¹ A number of studies have been published in the psychology literature regarding facial asymmetry and perceptions of attractiveness.^{2,3} These studies report that facial symmetry is an important factor in facial attractiveness.

Perfect bilateral body symmetry seldom exists, and mammals in particular have marked asymmetry in the size, shape and position of the internal organs. Brain function also exhibits asymmetry, a simple example being right and left-handedness. Craniofacial asymmetry may result from discrepancies in the size, shape or relative position of individual bones in the craniofacial complex and/or the overlying soft tissues.

Peck et al.⁴ evaluated bilateral facial skeletal symmetry in 52 'exceptionally well-balanced' white Caucasian adults and observed that the degree of asymmetry was greatest in the lower facial third, and that asymmetry reduced as the cranium was approached. Severt and Proffit⁵ analysed data from patients with dentofacial deformities over an 18-year period. Of the one-third

that exhibited facial asymmetry, the lower facial third was affected much more frequently than the middle or upper thirds. Only 5% had asymmetry of the upper face, 36% had asymmetry of the midface, mainly just involving the nose, whereas 75% had a deviation of the chin.

Relationship between symmetry and proportion

Facial proportions and facial symmetry are separate yet inter-related entities. In fact, the classical Greek descriptions of symmetry (Greek 'symmetria' συμμετρία: a term blending the concept of symmetry with 'ideal' proportions) and proportion (Greek 'analogia' αναλογία: proportion) are entirely interwoven.

In the first century BC the Roman architect Marcus Vitruvius Pollio wrote the ten-volume *De Architectura* ('On Architecture'). In Book III, Chapter 1, Vitruvius wrote:

'The design of a temple depends on symmetry, the principles of which must be most carefully observed by the architect. They are due to proportion, in Greek 'analogia' αναλογία. **Proportion** is a proper agreement between the measures of the parts of an entire work, and the relation between the different parts and the whole general scheme, in accordance with a certain part selected as standard. The principles of **symmetry** result from proportion. Without symmetry and proportion there can be no principles in the design of any temple. Thus in the *well proportioned* human body there is a kind of

symmetrical harmony ... and so it is with perfect buildings.⁶ [emphasis added]

The principles that Vitruvius described for architecture were based on those described by classical Greek sculptors. These same principles of correct proportions and symmetry are the foundation of diagnosis and treatment planning in the management of craniofacial deformities.

Note

It is worthwhile remembering that a face may be disproportionate but symmetrical; but a well-proportioned face cannot exhibit significant asymmetry.

Balance and harmony: a note on terminology

'It is a safe rule to apply that, when a mathematical or philosophical author writes with a misty profundity, he is talking nonsense.'

Alfred North Whitehead (1861–1947), English mathematician and philosopher, *An Introduction to Mathematics* (1911)⁷

The terms **balance** and **harmony** are often used by clinicians when describing facial aesthetics. Left-right balance of the face refers to symmetrical relationships, whereas balance between the vertical facial thirds refers to proportional relationships. The term **harmonious proportions** again refers to ideal proportional relationships, whereas a **harmonious facial profile** often simply means a profile that is pleasing to the eye. Both these terms are non-specific and in the clinical setting may serve to confuse. The terms balance and harmony should ideally only be employed when the particular aspect being described is clearly specified; otherwise it is better to employ accurate and quantifiable terms, such as symmetry and proportion, when describing craniofacial morphology.

Aetiology and classification of facial asymmetry

Facial asymmetry may be caused by a range of factors that affect the underlying facial skeleton and/or its overlying soft tissues.

Aetiology

Patients with a significant, true skeletal and/or soft tissue facial asymmetry may have a **developmental** condition, or a growth anomaly resulting from **trauma**. A complete patient history

and medical history, in-depth clinical and radiographic assessment and an evaluation of the developmental status in children will usually permit the development of a differential, if not definitive, diagnosis. Patients with **congenital** craniofacial syndromes are often relatively easy to recognize from the physical appearance, e.g. hemifacial microsomia, craniosynostoses (Crouzon and Apert syndromes) and Treacher Collins syndrome.

Classification

A number of methods have been described to classify the numerous conditions resulting in facial asymmetry. Any attempt to bring order to such a group of disparate conditions is helpful, even if the various classifications crosscut each other.^{8,9} A useful classification system involves broadly separating the causes of facial asymmetry into three groups: congenital, developmental and acquired (Table 10.1).^{8,9}

Congenital anomalies are conditions acquired during prenatal development, which are usually observed at birth, and may be further subdivided into malformations, deformations and disruptions.

- A **malformation** is a morphological defect (of an organ, part of an organ, or a larger area of the body) resulting from an intrinsically abnormal developmental process, e.g. unilateral cleft lip. The earlier in embryogenesis such defects are initiated, the more complex the resulting malformation.
- A **deformation** is an abnormal form or position of a part of the body caused by non-disruptive mechanical forces.
- A **disruption** is a morphological defect (of an organ, part of an organ, or a larger area of the body) resulting from a breakdown of, or interference with, an originally normal developmental process.

Developmental anomalies are conditions arising during post-natal growth through adulthood. For example:

- **Mandibular asymmetry:** Mandibular asymmetry is a potentially important factor in the perception of facial attractiveness. Asymmetry of the lower third of the face often results from asymmetrical growth of the mandible, which may be predominantly horizontal in direction (**hemi-mandibular elongation**), predominantly vertical (**hemi-mandibular hyperplasia**) or a combination of the two (see Chapter 19).¹⁰

Acquired anomalies are conditions arising from either trauma or pathology. Examples of pathological conditions include condylar resorption due to:

- Juvenile rheumatoid arthritis: Often results in severe mandibular deficiency, which may be asymmetrical.
- Adult-onset rheumatoid arthritis: Arthritic degeneration may destroy the condylar process and the resulting deformity may be asymmetrical if one mandibular condyle is affected to a greater extent than the other.

Table 10.1 A classification of the aetiology of facial asymmetry

Aetiology		Examples
Congenital (prenatal)	Malformations	Cleft lip and palate (unilateral) Hemifacial microsomia Hemifacial hyperplasia Plagiocephaly
	Deformations	Mandibular deformation resulting from sharp lateral flexion of the head with the shoulder pressed against the mandible in late intrauterine growth ⁹
	Disruptions	Rare facial clefting
Developmental (postnatal)	Intrinsic jaw growth anomalies	Hemimandibular elongation Hemimandibular hyperplasia Unilateral condylar hyperplasia
	Secondary jaw growth anomalies	Hemifacial atrophy (Parry–Romberg syndrome) Sternocleidomastoid torticollis Duchenne muscular dystrophy Cerebral palsy
	Functional	Lateral mandibular displacement
Acquired	Traumatic	Condylar trauma Maxillary/facial trauma
	Pathological	Condylar resorption Infection/inflammation Cysts Tumours
		Juvenile rheumatoid arthritis Adult-onset rheumatoid arthritis

Clinical evaluation

Purpose of the clinical evaluation

When evaluating the craniofacial structures for asymmetry, the purpose of the clinical examination is threefold:

- **Qualitative analysis:** Identifying the specific location(s) of the facial asymmetry (skeletal and/or soft tissue).
- **Quantitative analysis:** Objectively quantifying the degree of facial asymmetry.

Having undertaken a thorough clinical examination, the third step is:

- **Craniofacial growth assessment:** To determine, as far as possible, the location(s), magnitude and direction of any further growth of the craniofacial complex.

As with all systematic clinical facial evaluation, an overall qualitative (visual, anthroposcopic) assessment is followed by a comprehensive quantitative (anthropometric and cephalometric) analysis. Having obtained the necessary data, a further qualitative assessment is carried out, to determine whether the results of the quantitative assessment corroborate the qualitative evaluation (i.e. look at the patient, then measure the face, and then look at the patient again).

Note

In addition to the clinical examination a full set of clinical photographs is also required. However, *clinical photographs are not a substitute for comprehensive clinical evaluation*, but do permit further facial analyses to be undertaken and form a record of the clinical observations.

The clinical evaluation should begin with the **frontal facial examination**.

Frontal facial examination

Bilateral symmetry

The face must be examined for **bilateral symmetry** with the patient in **natural head position** (NHP), bearing in mind that a small degree of asymmetry is present in most individuals and essentially normal. The clinician may need to make minor manual adjustments to the patient’s head position, as patients will often have developed a *compensatory head posture* to minimize the aesthetic impact of their facial asymmetry, often tilting their heads to the right or the left, around the sagittal axis (Figure 10.1).

Note

Severe craniofacial asymmetries are notoriously difficult to assess, as it is seldom possible to locate any bilaterally symmetrical facial structures in order to provide a baseline, e.g. the interpupillary plane, from which to assess the asymmetrical structures. However, analysis of dentofacial asymmetries of the midface and in particular the lower facial third, such as localized mandibular or chin asymmetries, may be more straightforward, particularly if the upper facial third and orbits are relatively symmetrical and capable of providing baseline reference landmarks and planes, e.g. the interpupillary plane.



Figure 10.1 This patient developed a compensatory head posture, rotating his head around the sagittal axis.

Facial midline (midsagittal plane)

With the patient in NHP, a **true horizontal line** may be drawn through the mid-glabellar region (soft tissue glabella), midway between the eyebrows, perpendicular to a true vertical, e.g. a plumb line from the ceiling. From this true horizontal line, a perpendicular facial midline (midsagittal plane) may be constructed from glabella (Figure 10.2).



Figure 10.2 Facial midline, parallel to a true vertical line (TrV).

In less severe dentofacial deformities, the mid-philtrum of the upper lip (midpoint of Cupid's bow) will commonly be in the midline of the face, except in exceptional circumstances, e.g. cleft lip or severe nasal asymmetry distorting the upper lip. A line joining this point to soft tissue glabella forms the facial midline. In the symmetrical face, this line will extend to the midpoint of the chin (soft tissue pogonion). The midpoint of the nasal bridge and the nasal tip (pronasale) should be on this line if the nose is symmetrical (Figure 10.3).

With the lips slightly separated, the maxillary and mandibular dental midlines may be assessed in relation to the facial midline, in particular to the mid-philtrum of the upper lip (midpoint of Cupid's bow). Having obtained the patient's permission, *these points may be marked on the patient's face with a skin pencil*, in order to permit more accurate assessment (Figure 10.4).

Note

In patients with normal symmetry of the upper face and orbits and the absence of vertical orbital dystopia, a horizontal **interpupillary line** may be drawn, which will be parallel to the true horizontal line.

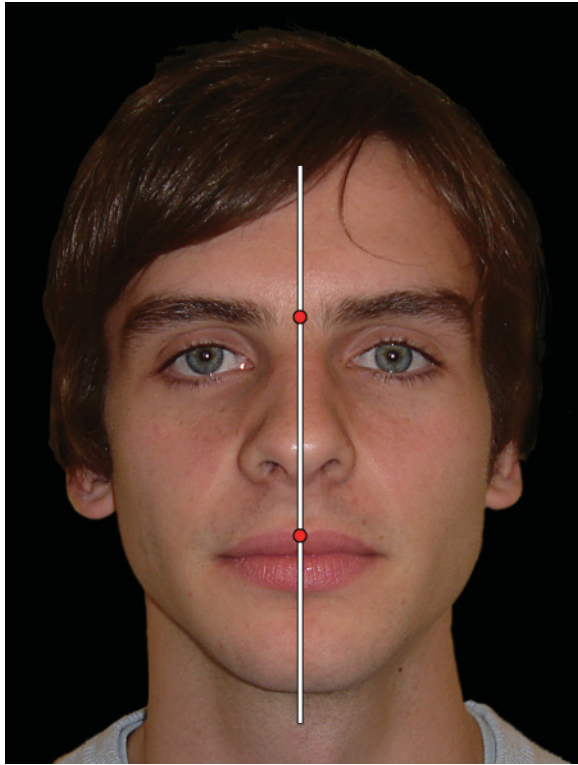


Figure 10.3 Facial midline, connecting glabella and the mid-philtrum of the upper lip (midpoint of Cupid's bow).

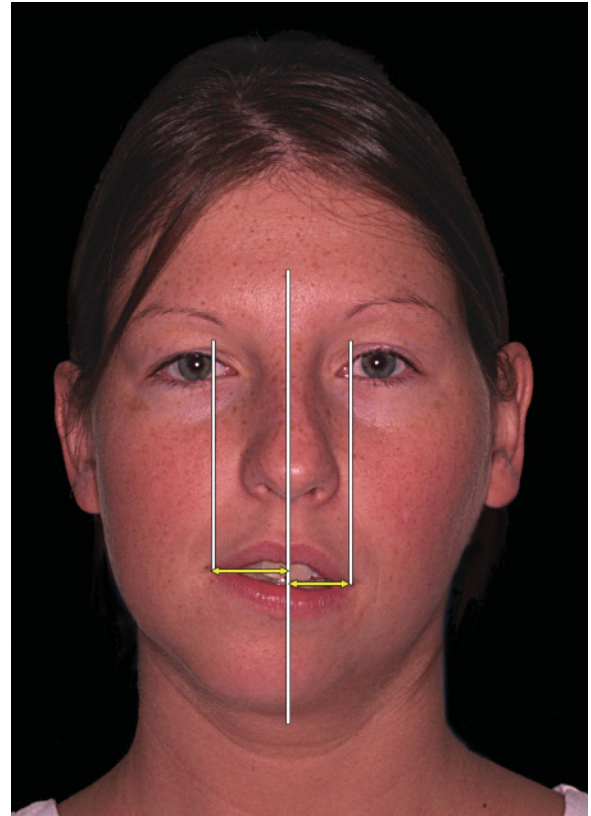


Figure 10.5 Vertical references lines.

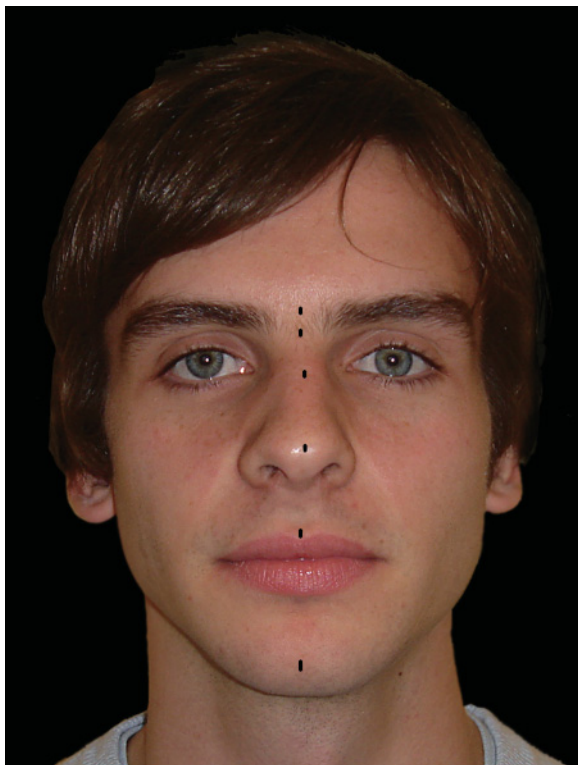


Figure 10.4 The midpoints of different structures may be marked on the patient's face with a skin pencil.

Vertical reference lines/planes (Figure 10.5)

Having established the facial midline, further vertical lines may be drawn parallel to facial midline through *any pair of bilateral landmarks* suspected of being asymmetrical. It is then possible to assess:

- The orientation of these lines in relation to the facial midline and the bilateral structures that they pass through.
- The horizontal distance of each of the bilateral landmarks to the facial midline.

Horizontal (transverse) reference lines/planes (Figure 10.6)

Horizontal reference lines may be constructed by connecting bilateral landmarks. It is then possible to assess:

- If the lines are perpendicular to the facial midline.
- The **relative orientation** of the various lines, which should ideally be parallel to one another, with the absence of transverse cants.
- The vertical level of bilateral structures to a baseline horizontal reference line, e.g. left and right cheilion (the angle of the mouth) to a horizontal line through subnasale (Figure 10.7). Such linear measurements may be used anthropometrically or on facial photographs and three-dimensional (3D) facial soft tissue scans if landmark identification is reliable.

Note

In terms of the interpupillary line, it is important to bear in mind that in some craniofacial anomalies there may be significant **vertical orbital dystopia**, i.e. the orbital structures may be asymmetrical, at different vertical levels. Therefore, in such patients, rather than use the interpupillary line, it is necessary to draw a true horizontal line, perpendicular to a true vertical line, with the patient in NHP.

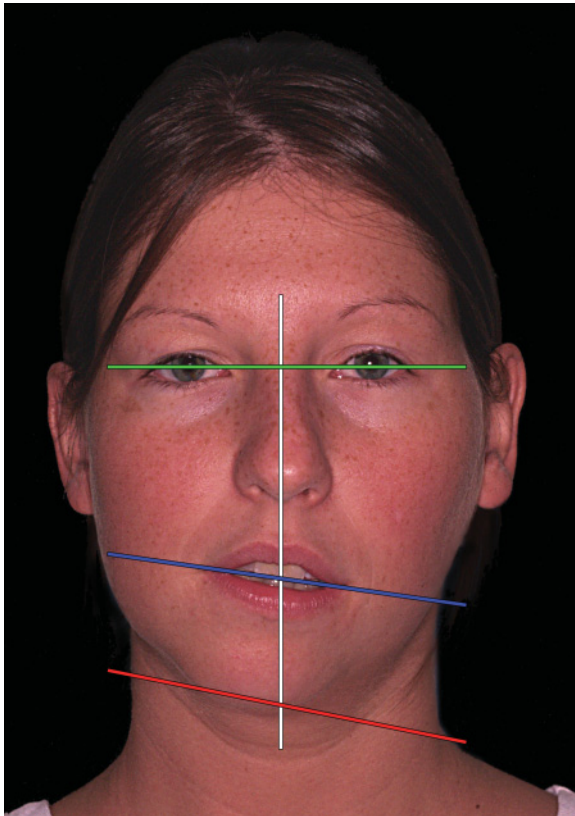


Figure 10.6 Horizontal reference lines.

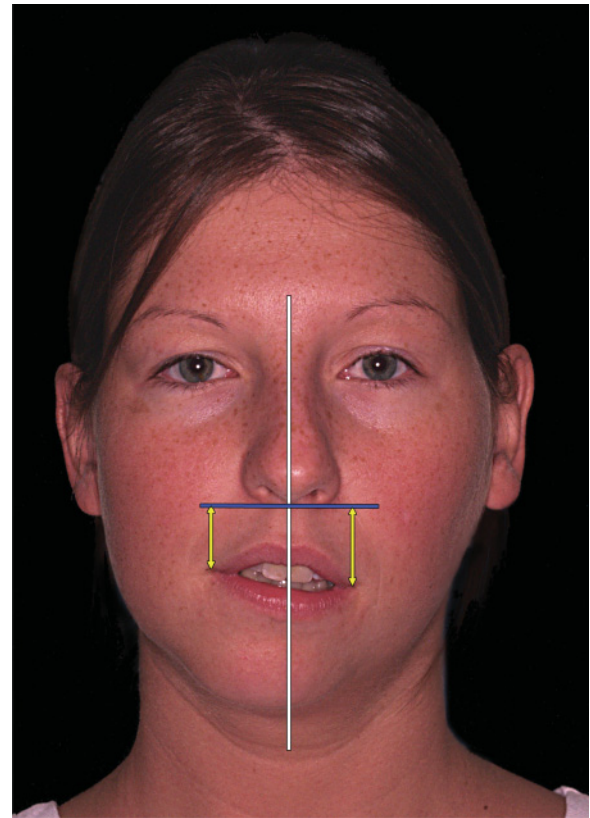


Figure 10.7 The vertical level of bilateral structures to a baseline horizontal reference line may be used to evaluate bilateral facial symmetrical relationships.

The presence of a **cant** in the **transverse occlusal plane** may be observed in relation to the interpupillary line (or a true horizontal plane) with the patient biting on a wooden spatula (or holding it against the maxillary teeth if there is a lateral open bite), both in the incisor/canine region and the premolar/molar region (Figure 10.8), or a Fox's occlusal guide plane



Figure 10.8 Use of wooden spatula to evaluate the orientation of the transverse maxillary occlusal plane.



Figure 10.9 Use of Fox's occlusal guide plane to evaluate the orientation of the transverse maxillary occlusal plane.

(Figure 10.9). In the absence of a transverse maxillary cant and/or vertical orbital dystopia, the transverse occlusal plane should be parallel to the interpupillary plane.

Following the frontal facial clinical examination, the asymmetrical face may be evaluated clinically and photographically from a number of different views.

Superior view (Figure 10.10)



Figure 10.10 The superior view.

The superior view is taken directly from above and behind, with the patient's head hyperextended. This view is useful for assessment of the symmetry of the nasal bridge, and the horizontal projection of the forehead, orbits and particularly the zygomas and paranasal areas.

Submental view (Figure 10.11)

The submental view is taken directly from below, with the patient's head hyperextended. This view is required to assess the symmetry of the mandibular body and the base of the nose, and is also useful for assessing any asymmetrical projection of the forehead, orbits, zygomas and paranasal areas.

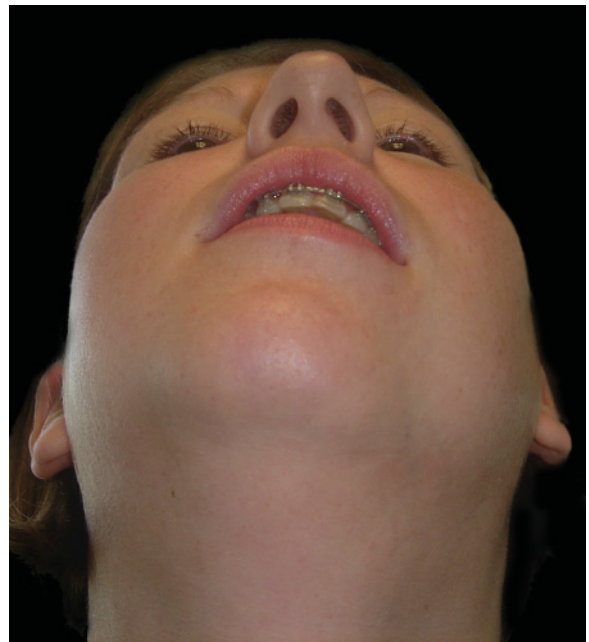


Figure 10.11 The submental view.

Lateral view

The left and right profile views may be used to compare the contours of the left and right sides of the face. This view is particularly useful for assessment of asymmetry in the contour of the inferior border of the mandible.

Oblique lateral (three-quarter) view

These views are taken with the patient in NHP, and are useful for assessment of asymmetry of the nose, zygomas, paranasal areas and the mandibular ramus and body outline, including the gonial angle.

Transverse occlusal plane view

This view is ideally taken with the patient in NHP. An orthodontic cheek retractor may be placed in order to retract the lips and cheeks (Figure 10.12); alternatively an assistant may stand behind

the patient and retract the cheeks using photographic retractors (Figure 10.13). A transverse cant of the maxillary occlusal plane may be assessed in relation to a true horizontal plane or to the interpupillary plane in the absence of vertical orbital dystopia.

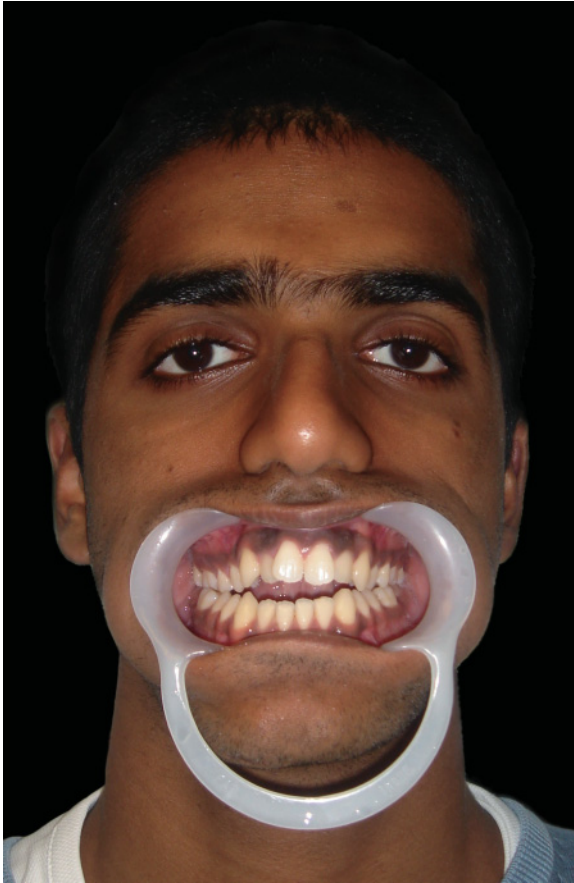


Figure 10.12 Transverse occlusal plane view with an orthodontic cheek retractor in position.



Figure 10.13 Transverse occlusal plane view with photographic retractors.

Dynamic clinical evaluation

Mandibular lateral displacement

The basic position of the mandible in relation to the rest of the facial skeleton is referred to as the **rest position**. The muscles acting on the mandible are in a relaxed state and the condyles are in retruded, unstrained positions within the glenoid fossae. This overall position is also referred to as **centric relation**. In the rest position, the teeth are out of contact by 2–3 mm, referred to as the **freeway space**. When the teeth occlude into maximum intercuspation the mandible should also be in a position of centric relation. Ideally the path of closure of the mandible from the rest position to the position of maximum intercuspation of the teeth should be a simple hinge movement over the 2–3 mm of the freeway space, with the condyles rotating in their glenoid fossae.

Occasionally as the path of closure starts from the rest position, there is an initial, **premature contact** of the upper and lower teeth. This is uncomfortable for the patient, necessitating a **displacement** of the mandible to obtain maximum intercuspation of the teeth. If this displacement or **functional shift** of the mandible is in a lateral direction, then the patient may exhibit an *apparent* or *pseudo*- mandibular asymmetry (Figures 10.14 and 10.15).

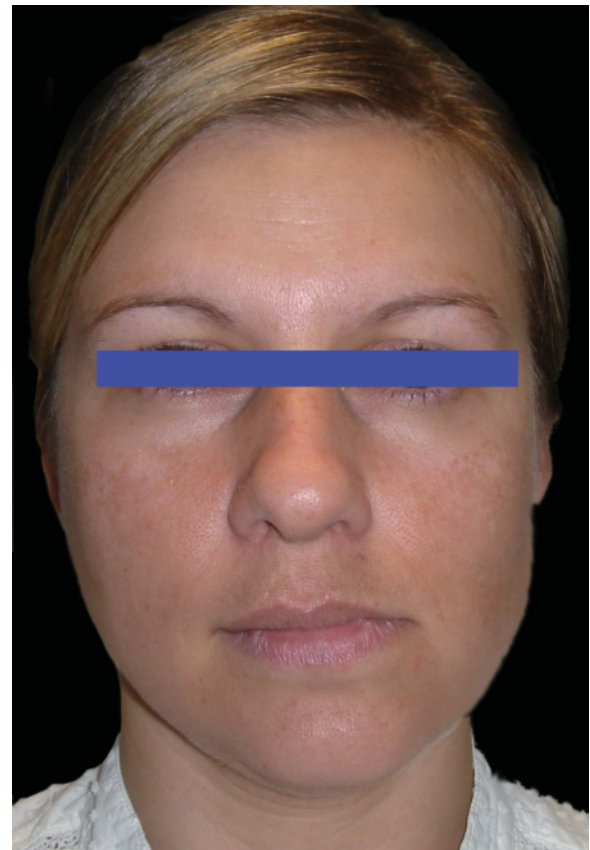


Figure 10.14 Mandibular asymmetry due to lateral mandibular displacement to the patient's left.

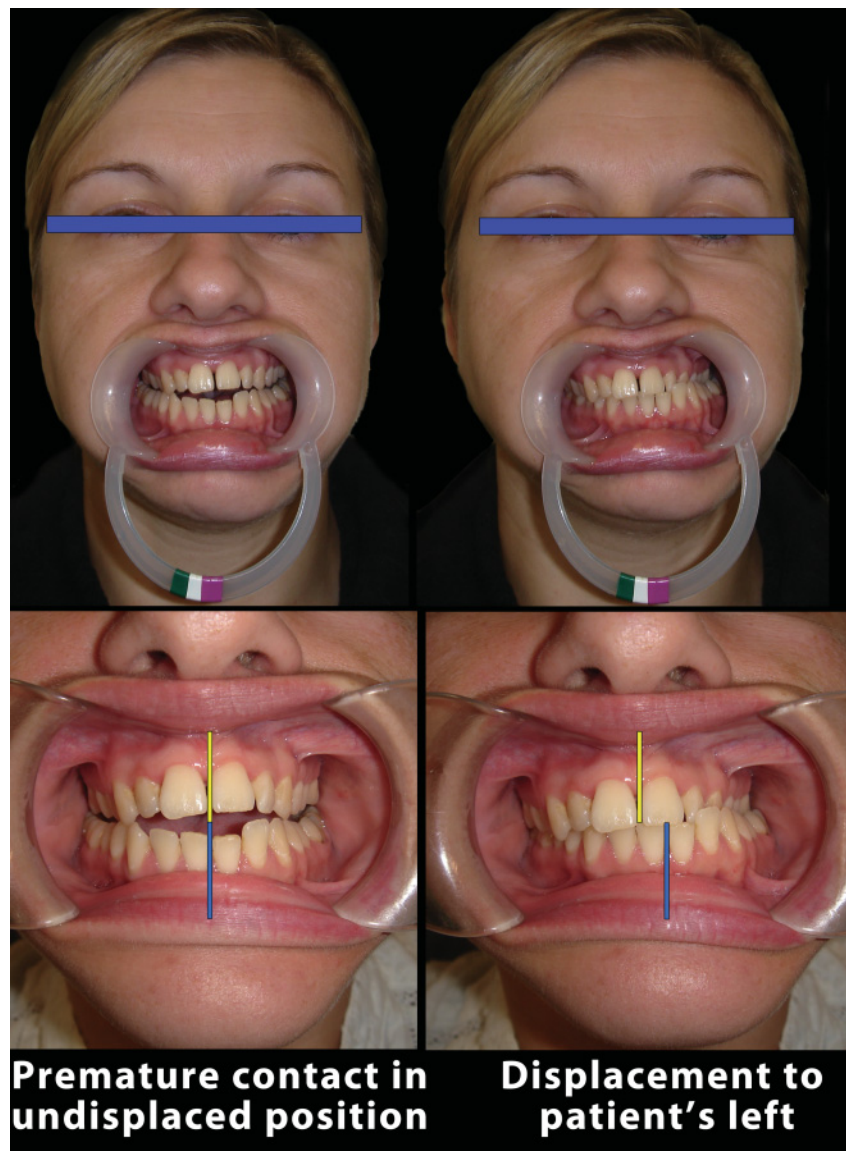


Figure 10.15 Premature contact in the undisplaced position, from which the symmetrical mandible is displaced to the left when the patient attempts to achieve maximum intercuspatation of the teeth, creating an *apparent* mandibular asymmetry (i.e. a pseudo-asymmetry).

It is important to evaluate the mandible on opening and closing, in order to check for displacements/functional shifts. Assess the patient from the front, and then stand above and behind the patient as they open and close the mouth, in order to assess any lateral mandibular movement on opening and/or closing. If a lateral mandibular displacement is present, the asymmetry should reduce as the patient opens the mouth, with the upper and lower dental midlines becoming better aligned (Figure 10.16).

With longstanding mandibular displacements the pattern of muscular activity is sometimes such that the displacement cannot be identified by observation alone. Therefore, if no displacement is observed, it is important to double check by clinically manipu-

lating the mandible into occlusion. Place the knuckle of your curled index finger under the patient's chin and your thumb on the mental eminence. Ask the patient to relax, then apply gentle pressure to move the mandible up and down, aiming to keep the condyles in their retruded position within the glenoid fossae. Look for the initial, premature dental contact; the patient may be better able to identify this area and point it out to you. Having established the premature contact, ask the patient to bite together and the displacement will become evident.

It is absolutely vital to check for mandibular displacements in cases of mandibular asymmetry, as missing a lateral mandible displacement may lead to the incorrect diagnosis of a true (i.e. skeletal) mandibular asymmetry and inevitably to incorrect

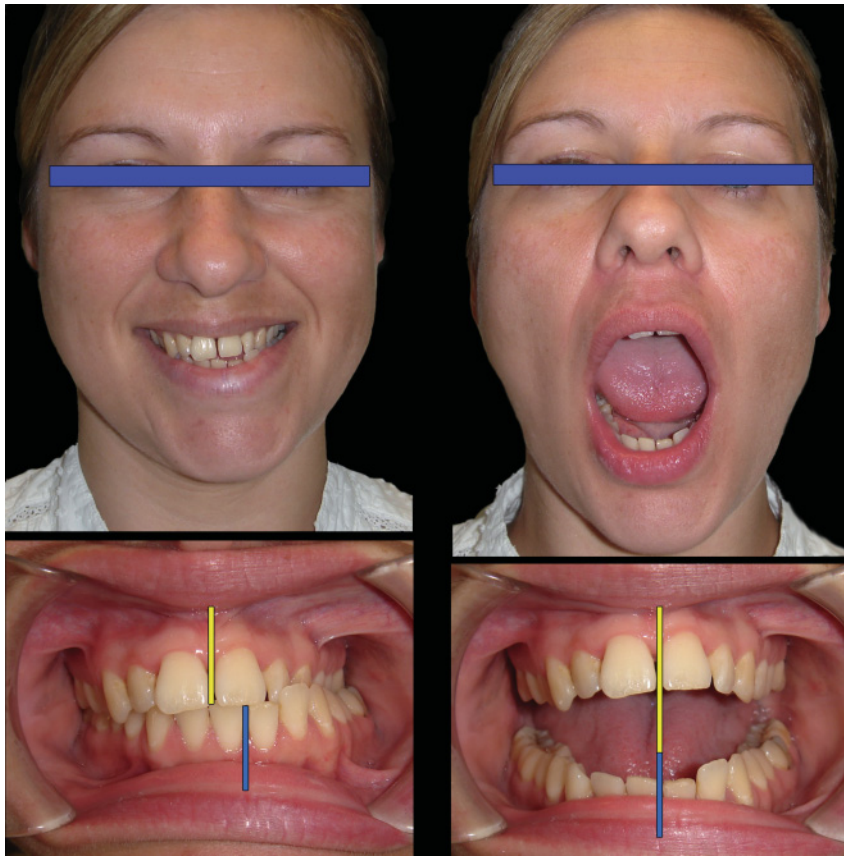


Figure 10.16 On mouth opening the upper and lower dental midlines are almost coincident.

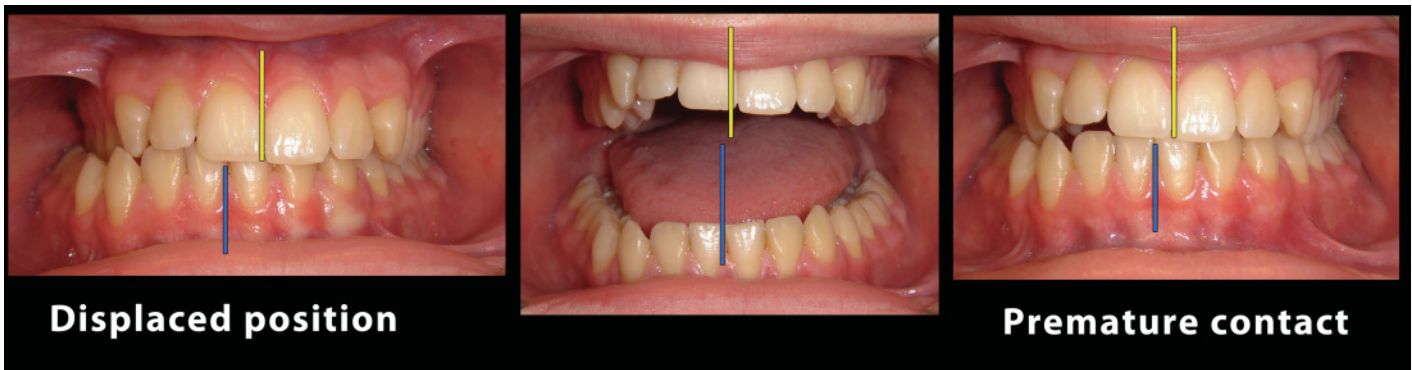


Figure 10.17 Mandibular asymmetry is evident in the undisplaced position, but is exaggerated by a mandibular displacement to the same side.

treatment. It is also important to bear in mind that a patient may present with a combined true mandibular asymmetry and a lateral mandibular displacement (Figure 10.17). The degree of true mandibular asymmetry must always be determined from the undisplaced position.

Asymmetrical facial animation

Some asymmetry in facial animation is relatively common. It is important not to mistake an asymmetry in facial animation with a dentoskeletal asymmetry, e.g. an asymmetrical smile where the

levator muscles of one side cause greater elevation of the upper lip than the contralateral side may be mistaken for a transverse cant in the maxillary occlusal plane.

Dental midlines

Maxillary dental midline

The upper dental midline should be aligned with the mid-philtrum of the upper lip.

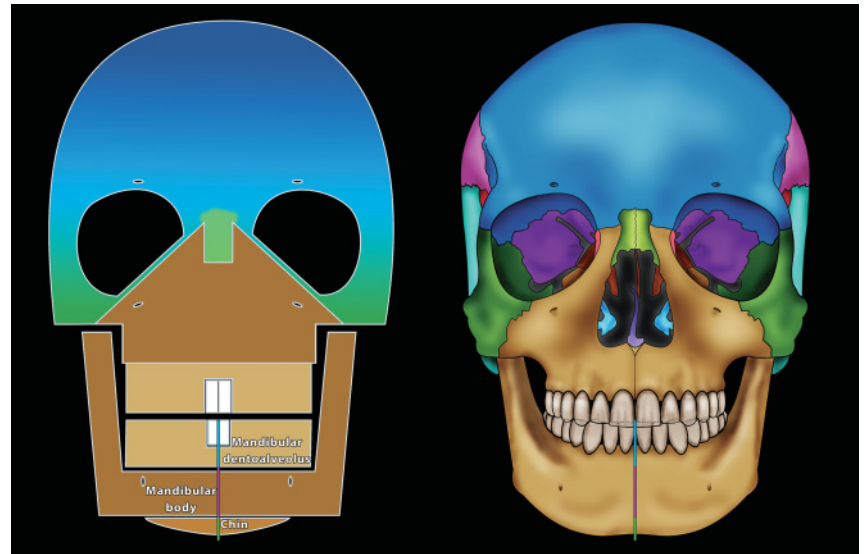


Figure 10.18 The mandibular dental midline should be evaluated in relation to the mandibular dentoalveolus, the mandibular body and the chin.

Mandibular dental midline

The lower dental midline must be assessed in relation to the upper dental midline and to three anatomically related segments of the anterior mandible (Figure 10.18):

- **Dentoalveolar segment:** The lower dental midline may be to the left or right of the facial midline due to dental crowding or spacing causing lateral movement of the incisor teeth.
- **Body of the mandible:** Asymmetrical growth of the mandible due to, e.g. hemimandibular elongation will lead to a lower dental midline shift, as the mandibular incisors are carried by the mandible.
- **Chin proper:** Even in an asymmetrical mandible, the midpoint of the chin may be symmetrically or asymmetrically positioned in relation to the mandibular body.
 - **If the midpoint of the chin is symmetrical with the body of the mandible:** In this case, even if the body of

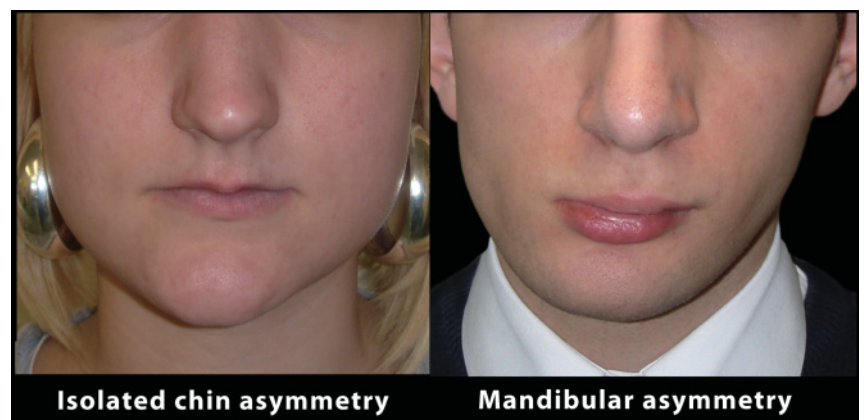
the mandible is asymmetrical, the lower dental midline needs to be correctly aligned to the midpoint of the mandible and chin. Surgical repositioning of the mandible to correct the facial asymmetry will thereby correct the dental midline discrepancy.

- **If the midpoint of the chin is not symmetrical with the body of the mandible:** The lower dental midline needs to be aligned with the midpoint of the mandibular body. When the asymmetrical mandible is surgically repositioned, the asymmetrical chin may also be repositioned by horizontal sliding genioplasty (see Chapter 20).

Distinguishing between mandibular and isolated chin asymmetry (Figure 10.19)

Asymmetry of the chin may be due to a **true mandibular asymmetry**, an **isolated chin asymmetry** or a combination of the two. It is very important to differentiate between these during the

Figure 10.19 Left panel: With isolated chin asymmetry, the upper and lower lips and oral commissures are essentially symmetrical. Right panel: With mandibular asymmetry, the relationship of the upper and lower lips tends to be asymmetrical too.



clinical evaluation. With an isolated chin asymmetry, the relationship of the upper and lower lips is usually symmetrical; the oral commissure plane and transverse occlusal plane will be parallel with the other horizontal planes of the face. In the absence of dental crowding/spacing, the dental midlines will coincide with the facial midline and with each other. When a mandibular asymmetry is present, the relationship of the upper and lower lips is often asymmetrical, the oral commissure plane and transverse occlusal plane are often canted and the dental midlines may not be coincident. The definitive diagnosis may be confirmed by radiographic examination. It is critical to make a correct diagnosis.

Radiographic-cephalometric evaluation

Posteroanterior cephalometric radiograph

The posteroanterior (PA) cephalometric radiograph is indicated when a clinically significant facial asymmetry is evident. Analysis of this radiograph will permit the evaluation of any underlying dentoskeletal asymmetry.

Midsagittal plane

The first step in analysis is the identification of the midsagittal plane. A number of different methods may be used to establish a facial midline on the PA cephalometric radiograph:

- **Drawing a true vertical line in the facial midline** (Figure 10.20): This is the recommended method. The radiograph must be taken with a very precise technique with the patient in natural head position (NHP), taking care to avoid rotation of the patient's head about the sagittal or vertical axes. A true vertical line is drawn in the facial midline, parallel to a plumb line hanging from the ceiling. Horizontal planes may be drawn perpendicular to this true vertical plane.
- **Constructing a midline perpendicular to a horizontal plane:** It is possible to construct a horizontal plane by connecting bilateral skeletal structures and constructing a perpendicular vertical line from a midpoint landmark. The problems with this method are:
 - Difficulty in determining which landmark or constructed point to use
 - Any small variation in the horizontal plane can produce a large deviation in the constructed facial midline (Figure 10.21).¹¹

Harvold¹² found that the zygomaticofrontal sutures and the crista galli process of the ethmoid bone were relatively symmetrical structures compared with other skeletal landmarks further from the cranial base. He recommended the construction of a horizontal plane through the lateral parts of the zygomaticofrontal sutures (Figure 10.22). The midsagittal plane may then be constructed perpendicular to this horizontal, passing through the root of the crista galli. Harvold¹² suggested that in 90% of the population the anterior nasal spine will be less than 1.5 mm from this constructed midline.

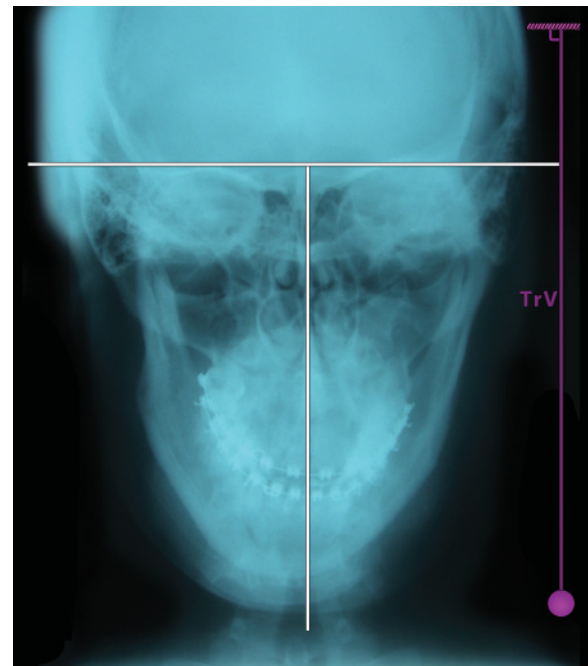


Figure 10.20 Posteroanterior cephalometric radiograph demonstrating a true horizontal plane perpendicular to and a true vertical plane parallel to a true vertical line (TrV, e.g. a plumb line hanging from the ceiling).

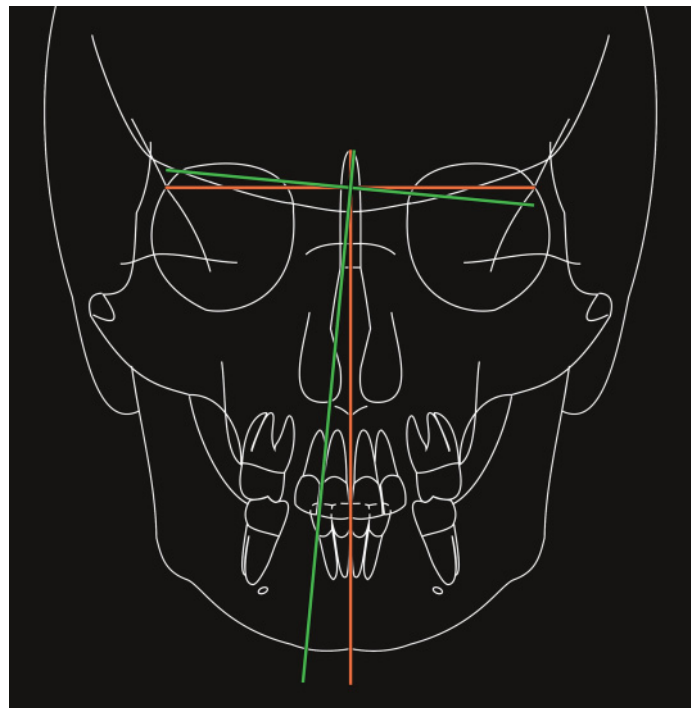


Figure 10.21 In establishing a facial midline perpendicular to a constructed horizontal plane, small variations in the orientation of the horizontal plane can lead to large variations in the orientation of the facial midline.

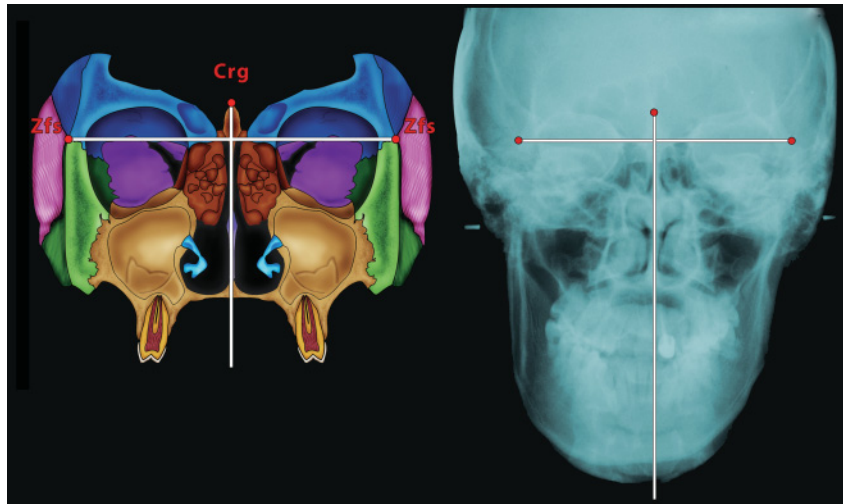


Figure 10.22 Harvold¹² recommended the construction of a horizontal plane through the lateral parts of the zygomaticofrontal sutures; the midsagittal plane may be constructed perpendicular to this horizontal. Zfs, zygomaticofrontal suture; Crg, crista galli.

- **Connecting midsagittal landmarks:** A number of midline landmarks may be identified and connected. However, these points will not always fall along the same vertical line due to a number of reasons:
 - The presence of a genuine facial skeletal asymmetry
 - Difficulty in landmark identification
 - Head rotation around the vertical axis in the cephalostat.
- **Constructing midline landmarks by connecting the mid-points between bilateral structures:** Selecting midpoints between bilateral structures creates midpoints that are not always in vertical alignment. These therefore cannot be used to construct a facial midline even in patients with relatively symmetrical faces because:
 - Faces are commonly asymmetrical, with one side larger and wider than the other
 - Rotation of a symmetrical head around the vertical axis in the cephalostat.¹¹
- **Taking the radiograph with radiopaque soft tissue markers** (Figure 10.23): A number of soft tissue midline points, such as soft tissue glabella, soft tissue nasion, pronasale, the mid-philtrum of the upper lip and soft tissue pogonion, may be marked with metallic markers or barium cream prior to taking the radiograph. The dentoskeletal structures may be compared with the soft tissue midline.

Note

The construction and establishment of a skeletal facial midline and midsagittal plane is important, but subject to many inaccuracies. The diagnosing clinician must appreciate these limitations.¹¹

Vertical reference lines/planes (Figure 10.24)

Vertical reference planes may be used to illustrate transverse skeletal asymmetries. Having established a midsagittal plane, further vertical lines may be drawn parallel to the midsagittal plane through *any pair of bilateral landmarks* suspected of being asymmetrical. It is then possible to assess:

- The orientation of these lines in relation to the facial midline and the bilateral structures that they pass through.
- The horizontal distance of each of the bilateral landmarks to the facial midline. This is possible, but generally unnecessary as there is a likelihood of forward or backward tilting of the head and/or head rotation about the vertical axis, which will affect such linear measurements.

Horizontal (transverse) reference lines/planes (Figure 10.25)

Horizontal reference planes may be constructed by connecting bilateral landmarks such as the superior orbital margins, inferior orbital margins, the left and right maxillary points, mastoid processes, maxillary molars, gonial angles and the inferior border of the chin. These horizontal planes may be used to illustrate vertical dentoskeletal asymmetries. It is then possible to assess:

- If the lines are perpendicular to the facial midline.
- The *relative orientation* of the various lines, which should ideally be parallel to one another, with the absence of transverse cants.
- The vertical level of bilateral structures to a baseline horizontal reference line, bearing in mind that the use of such linear measurements on the PA cephalometric radiograph is somewhat unreliable due to the difficulty in landmark identification.



Figure 10.23 Soft tissue markers may be placed prior to taking posteroanterior cephalographs.

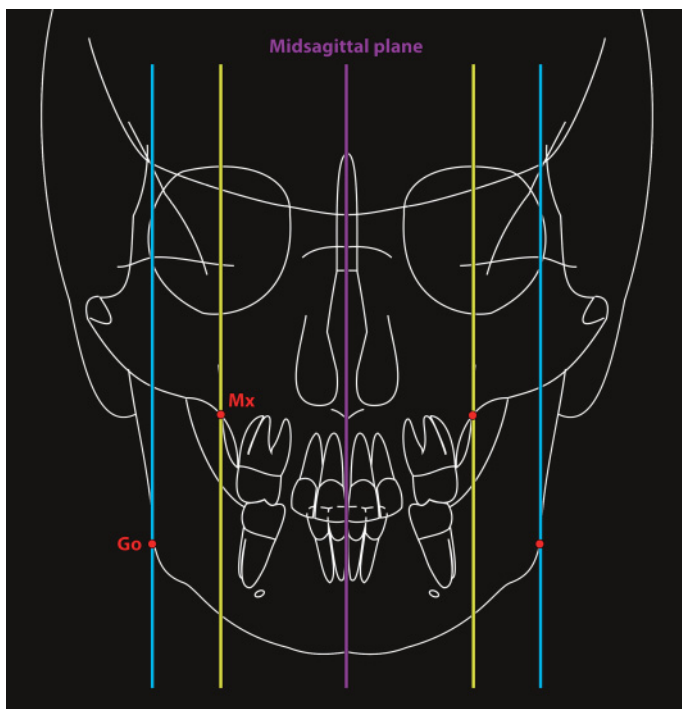


Figure 10.24 Vertical reference lines may be drawn parallel to the midsagittal plane through *any pair of bilateral landmarks* to help identify transverse skeletal asymmetries. Mx, maxillae; Go, gonion.

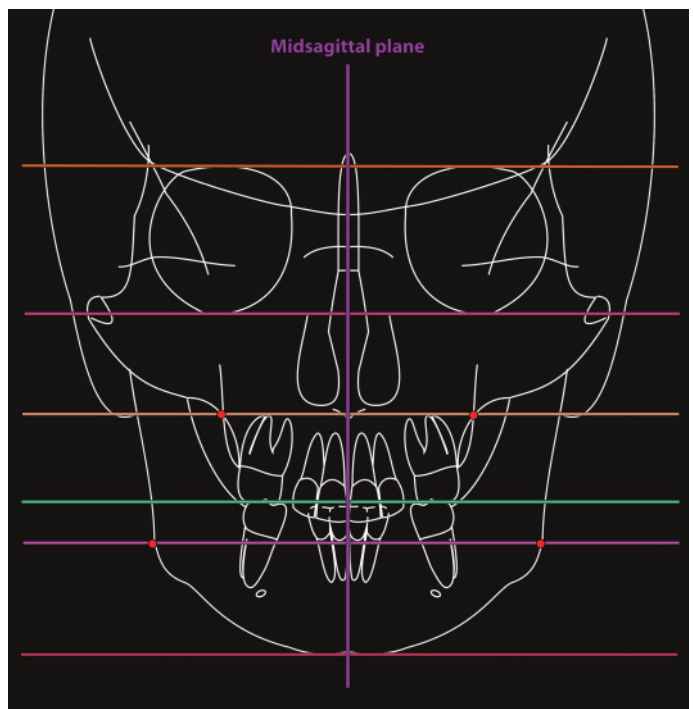


Figure 10.25 Horizontal reference lines may be used to illustrate vertical dentoskeletal asymmetries.

Triangular analysis

Vig and Hewitt¹³ described a triangulation method, which may be used in the assessment of skeletal asymmetry on a PA cephalometric radiograph. This approach has been modified by Grummons et al.¹⁴ and Reyneke.¹⁵ The first step is the construction of a midsagittal plane.

A useful method for constructing a midsagittal plane on the PA cephalometric radiograph is the following, based on constructing a midline perpendicular to a horizontal plane:

- A careful technique is employed in taking a high quality radiograph, particularly avoiding any rotation of the patient's head about the vertical axis.

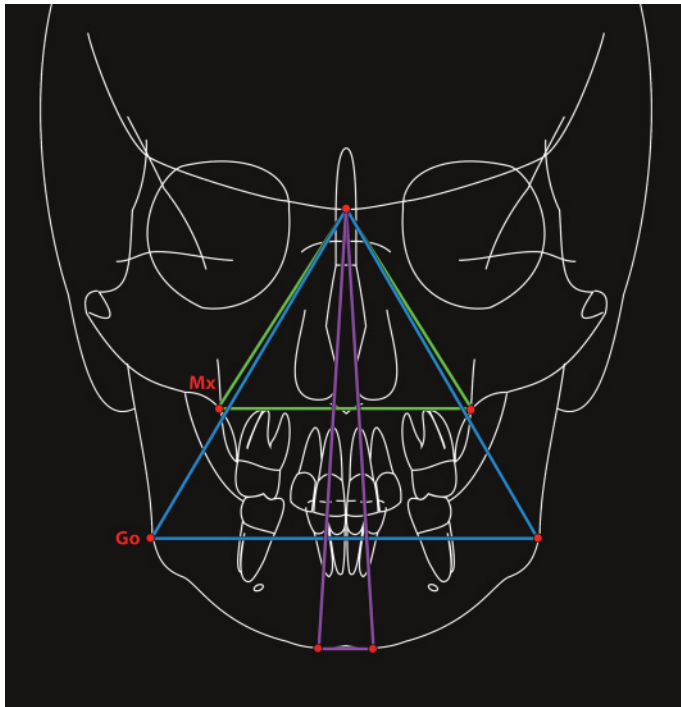


Figure 10.26 'Triangular analysis' demonstrating the maxillary, mandibular and chin triangles. Mx, maxillare; Go, gonion.

- The intersection of the lesser wing of the sphenoid and the medial orbital ridge is marked bilaterally, and the points are joined to form a horizontal line (referred to as the cranial base plane or C-plane).¹⁵
- A midline is constructed perpendicular to this horizontal line, through the roots of the crista galli of the ethmoid bone.¹²

Having constructed the midsagittal plane, the midpoint of the horizontal C-plane is marked; triangles may then be constructed to evaluate the symmetry of the maxilla, mandible and chin (Figure 10.26).

- **Maxillary triangle:** This is constructed by connecting the midpoint of the horizontal C-plane with points Mx (maxillare – intersection of the lateral contour of the maxillary alveolar process and the inferior contour of the zygomatic process of the maxilla) bilaterally.
- **Mandibular triangle:** This is constructed by connecting the midpoint of the horizontal C-plane with gonion bilaterally.
- **Chin triangle:** This is constructed by connecting the midpoint of the horizontal C-plane with the most inferior lateral point on the anterior inferior border of the mandible bilaterally.

Comparison of the long legs of the triangles demonstrates transverse cants of the maxilla, mandible and chin in relation to the cranial base and to each other. This is another method of comparing the orientation of the horizontal (transverse) planes.

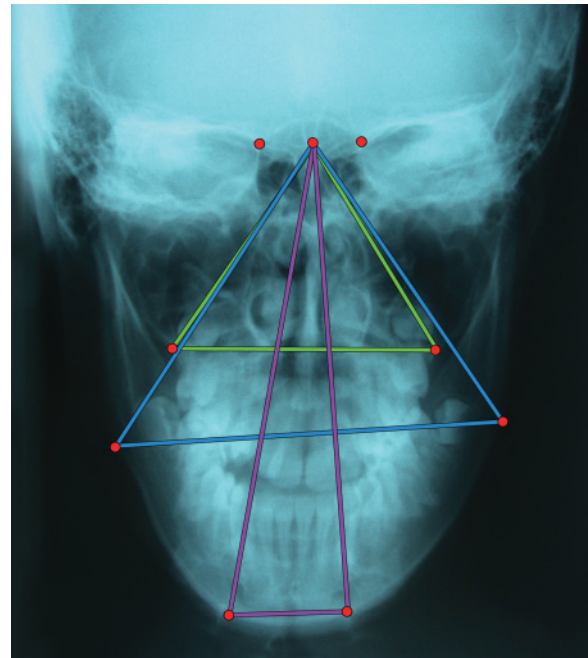


Figure 10.27 Right-sided hemimandibular hyperplasia has led to an increase in the right ramus height and asymmetry of the chin.

Comparing the left and right halves of the bases of the triangles will indicate asymmetry and left-right difference in size (assuming no rotation of the patient's head about the vertical axis) (Figure 10.27).

Lateral cephalometric radiograph

The lateral cephalometric radiograph must be taken with the patient in NHP. If clinical examination reveals that the patient's auditory canals are not level in the vertical plane with the patient in NHP, the cephalometric ear rods should not be used, to reduce the possibility of head rotation about the sagittal axis.

Lack of superimposition of bilateral structures may be observed in patients with facial skeletal asymmetry, in particular significant vertical differences between two separate inferior mandibular borders may indicate evidence of mandibular asymmetry, such as hemimandibular hyperplasia (Figure 10.28).

Panoramic rotational tomography (OPT – orthopantomograph)

The OPT may provide information regarding the relative height of the mandibular condyle, ramus and body bilaterally (Figure 10.29). Asymmetrical morphology may be identified with comparative bilateral measurements. Degenerative changes to the condylar heads, such as from condylar resorption, may be evident.

Note

It is important to bear in mind that radiologists, in jest, refer to the OPT as the 'distortograph'. The OPT is a very useful image from which to make an overall bilateral evaluation, but is not ideal for accurate comparison of left-right linear or angular measurements.

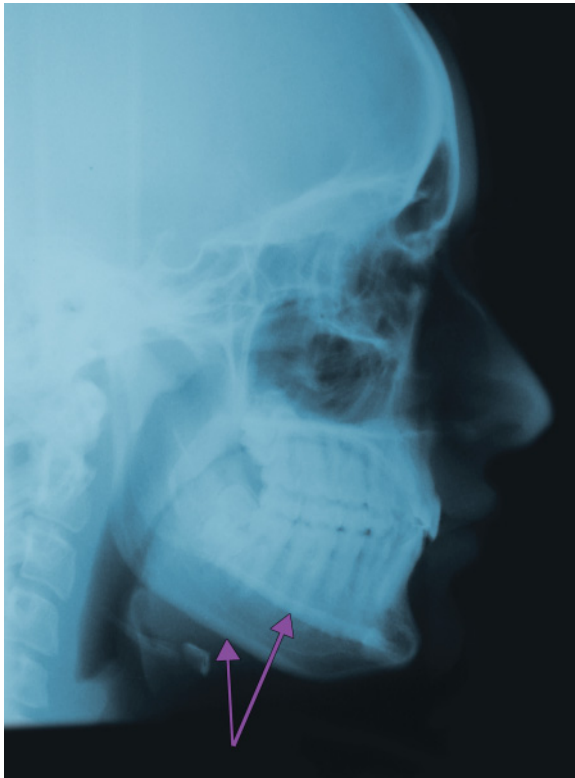


Figure 10.28 Vertical asymmetry of the left and right inferior mandibular borders is evident on a lateral cephalograph; superior structures are well superimposed.



Figure 10.29 Left-sided hemimandibular hyperplasia and excessive ramus height is evident on an orthopantomograph (OPT).

Three-dimensional imaging evaluation

The thorough clinical evaluation of patients presenting with complex dentofacial and/or craniofacial asymmetries will be enhanced by the analysis of 3D records.

Dental study casts

Dental casts of the occlusion are always useful when occlusal abnormalities are observed. Asymmetrical dental **arch forms** may be analysed by placing a transparent ruled grid over each arch, with the grid axis in the midline oriented over the mid-palatal raphe, allowing direct observation of distortions in arch form (Figure 10.30).

Dental casts are also useful in assessing whether any *progressive changes to the dental occlusion* are occurring over time, particularly in patients with mandibular asymmetries. In patients with hemimandibular hyperplasia, where a unilateral open bite or transverse cant of the maxillary occlusal plane is occurring, it is beneficial to mount the dental study casts on an adjustable articulator using a facebow transfer. A facebow is used to record the relationship of the patient's maxillary arch to the condylar hinge axis of the temporomandibular joints.

Three-dimensional facial soft tissue scans

3D facial soft tissue scans may be used to evaluate facial soft tissue morphology and to monitor asymmetrical growth by superimposition of serial scans (Figure 10.31). The main advantage is no radiation exposure and the possibility of combining 3D computed tomography (CT) views of the dentoskeletal

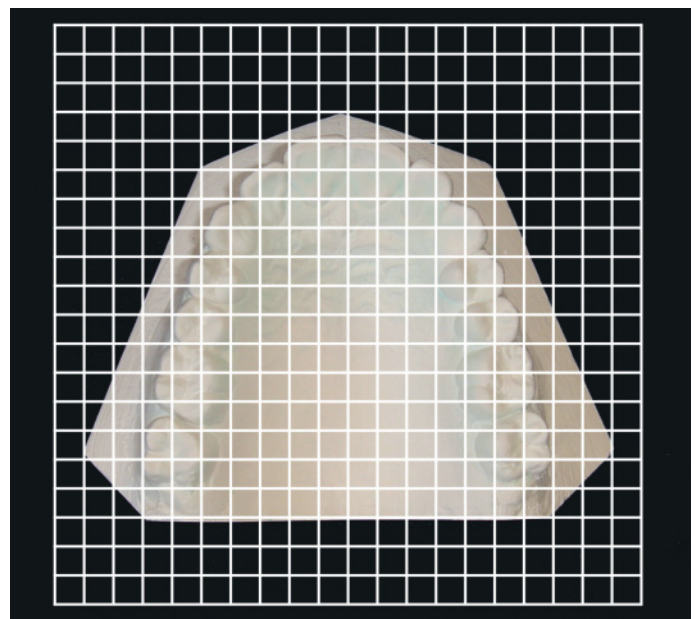


Figure 10.30 A transparent ruled grid may be placed over the occlusal surface of the dental study cast to evaluate asymmetries in arch form and in tooth position (sagittal and transverse discrepancies).

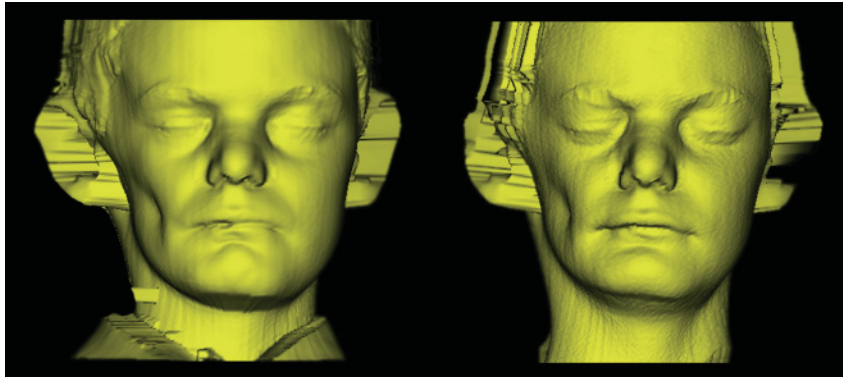


Figure 10.31 3D facial soft tissue scans of a developing facial asymmetry taken one year apart to monitor asymmetrical growth.

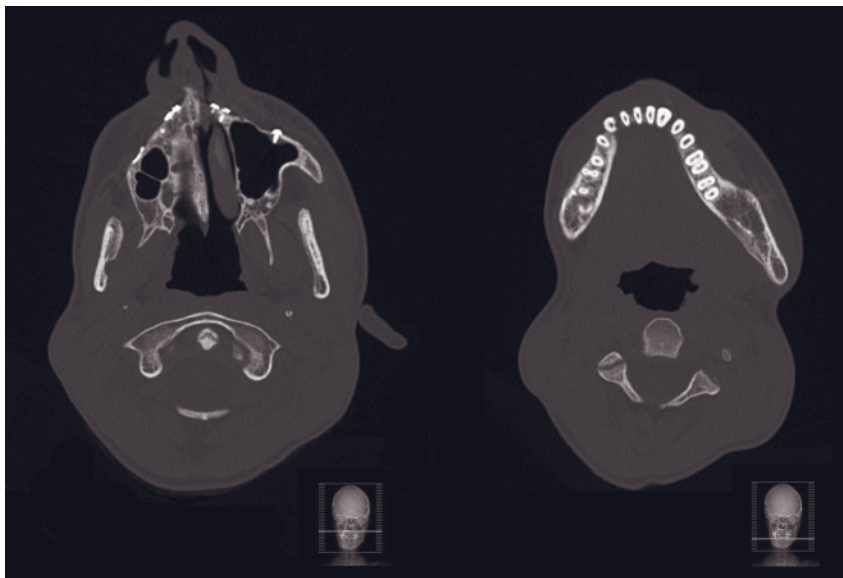


Figure 10.32 CT transverse sections of the maxilla and mandible in a patient with severe facial asymmetry.

structures with a 3D soft tissue facial surface scan. Such technology is currently expensive and the systems require further development.

Computed tomography

Information from CT scans may be used to provide two-dimensional localized views of the facial skeleton (Figure 10.32), or 3D computer images that can provide excellent dentoskeletal detail required for the diagnosis of complex dentofacial and craniofacial asymmetry (Figure 10.33).

- **Vertical and horizontal reference planes:** Vertical and horizontal reference planes similar to those described for the PA cephalometric radiograph may be employed, in addition to other reference planes where landmark identification is enhanced by the 3D image.

- **Vertical reference planes** (Figure 10.34): The guidelines are similar to the PA cephalometric radiograph. Additional vertical reference planes may be constructed through the supraorbital, infraorbital and mental foramina bilaterally (all related to the branches of the trigeminal nerve).

Note

In a symmetrical face, the supraorbital foramen or notch, infraorbital foramen and mental foramen are all in the same *vertical line*, although the supraorbital foramen may be slightly more medial in position (Figure 10.35).



Figure 10.33 Three-dimensional computed tomography reconstructions of patient in Figure 10.32.

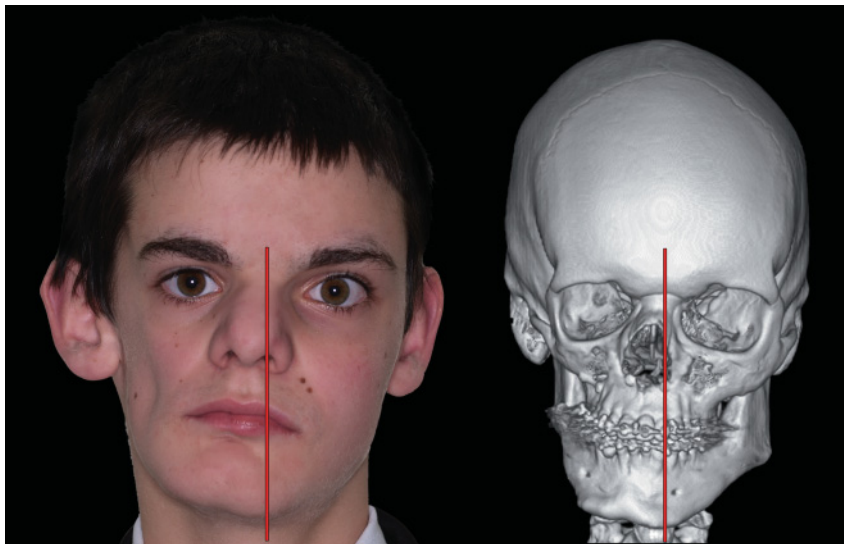


Figure 10.34 Having established the facial midline on a 3D computerized tomographic reconstruction (shown), further vertical lines may be drawn parallel to the facial midline through *any pair of bilateral landmarks* suspected of being asymmetrical. The orientation of these lines in relation to the facial midline may be evaluated, in addition to the horizontal distance of each of the bilateral landmarks to the facial midline.

- **Horizontal reference planes** (Figure 10.36): These may be represented by the construction of a horizontal plane through the lateral parts of the zygomaticofrontal sutures or the intersection of the lesser wing of the sphenoid and the medial orbital ridge bilaterally. Further horizontal planes may be constructed through the following points:
 - Supraorbital foramen bilaterally: represents the upper border of the orbital cavity
 - Orbitale bilaterally: represents the lower border of the orbital cavity
 - Bizygomatic plane: joining the two points zygion (Zyg) bilaterally

Image not available in the electronic edition

Figure 10.35 Vertical relationship of the trigeminal foramina (dotted blue line). (Detail, *Anatomical Study of the Human Skull*, Leonardo da Vinci, c. 1489; Royal Library, Windsor Castle.) (With kind permission from The Royal Collection © 2010 Her Majesty Queen Elizabeth II.)

- Zygomaticofacial foramen bilaterally
- Infraorbital foramen bilaterally
- Bimastoid plane: joining the two points mastoidale (Mas) bilaterally
- Maxillary plane: joining the two points maxillare (Max), essentially similar to jugale (J) bilaterally
- Maxillary occlusal plane: through the cusp tips of the maxillary molars and premolars
- Mandibular occlusal plane: through the cusp tips of the mandibular molars and premolars
- Bigonial plane: joining gonion bilaterally
- Mental foramina plane: joining the mental foramina bilaterally
- Inferior border of chin plane, through menton.

In the symmetrical facial skeleton, these lines are nearly parallel. Inspection of the CT scan will allow the clinician to observe the relative orientation of these horizontal planes to illustrate vertical dentoskeletal asymmetries.

- **Trigeminal foramina:** On a 3D CT, the vertical level of the trigeminal foramina may be evaluated for symmetry; it is possible to construct vertical lines through the supraorbital, infraorbital and mental foramina and also to connect the paired foramina to construct horizontal planes for assessment.

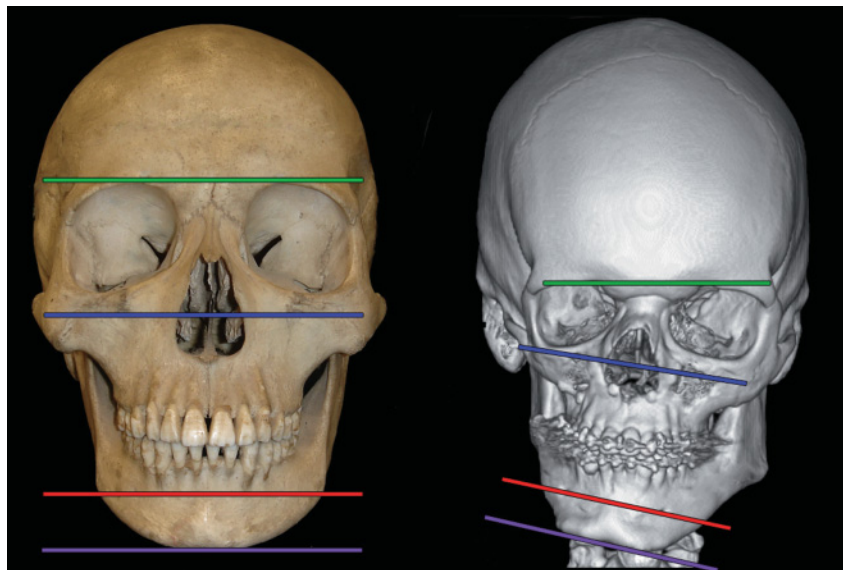


Figure 10.36 Horizontal reference planes drawn through bilateral structures will be nearly parallel in the symmetrical skull. The relative orientation of these horizontal planes will demonstrate vertical asymmetry. This figure illustrates horizontal planes through the supraorbital, infraorbital and mental foramina and the inferior chin plane.

Note

Treil et al.^{16,17} have described the use of a 3D cephalometric reconstruction, based on the selection on axial CT scans of ten anatomical landmarks, all of which were situated along the trigeminal 'neuromatrical' axis of facial growth. The landmarks selected were the mental foramen, infraorbital foramen, supraorbital foramen, mandibular foramen and the head of the malleus bilaterally in order to create a geometrical construction referred to as the **maxillofacial frame** (Figure 10.37).

- **Stereolithographic models** (Figure 10.38): Data from 3D CT scans may be used to fabricate a 3D stereolithographic dentoskeletal model of a patient.¹⁸ These models are particularly useful for diagnosis, treatment planning and model prediction surgery in complex craniofacial asymmetries.

Magnetic resonance imaging

Magnetic resonance imaging may provide useful diagnostic information if there is a significant soft tissue element to a

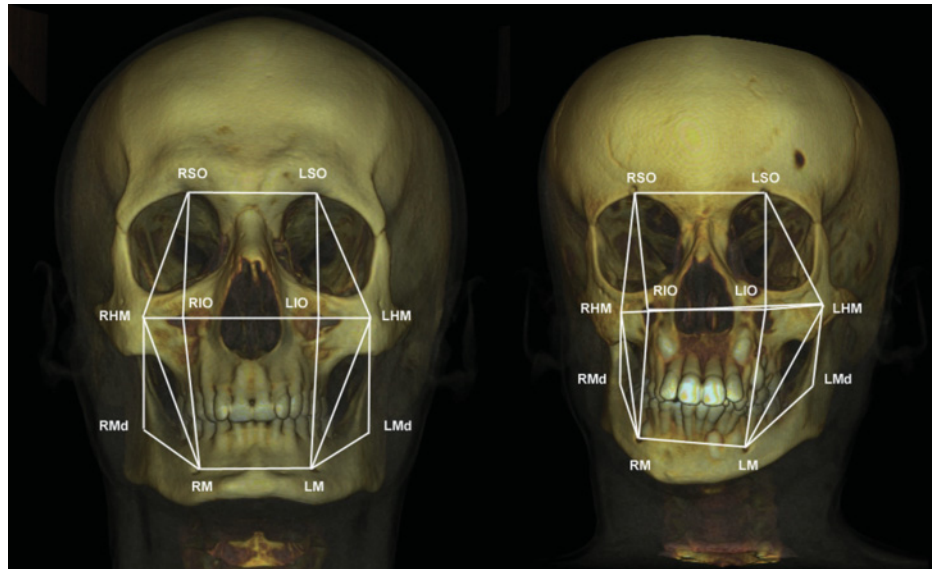


Figure 10.37 The 'maxillofacial frame' is a useful method of analysing facial symmetrical relationships. R, right; L, left; SO, supraorbital foramen; IO, infraorbital foramen; M, mental foramen; Md, mandibular foramen; HM, head of the malleus.

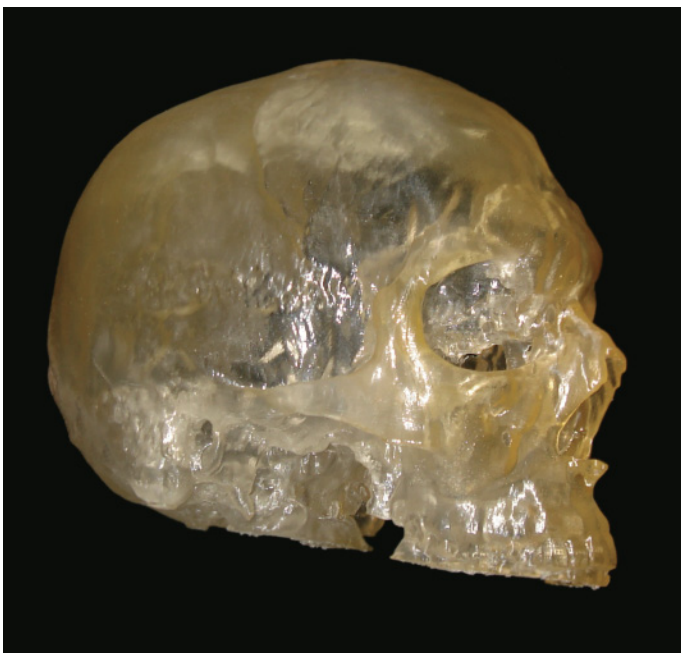


Figure 10.38 Stereolithographic model.

facial asymmetry, particularly when caused by pathological growth.

Craniofacial growth and treatment timing

When a patient presents with a significant facial asymmetry that is of concern, there are three key questions that must be asked:

- What is the **aetiology** of the asymmetry?
- Has **growth cessation** occurred?
- If not, is the **progressive asymmetry** due to a unilateral 'growth restriction' or 'continued excessive growth'?

Treatment timing

Treatment timing will largely depend on the answer to the three questions listed above. For example, unilateral growth restriction due to **ankylosis of the temporomandibular joint** (growth restriction) requires treatment. **Trauma** to the temporomandibular joints (leading to growth restriction) requires treatment.

If a **developmental mandibular asymmetry** (continued excessive growth) is identified at a young age, particularly if there is excessive unilateral mandibular growth in a vertical direction (hemimandibular hyperplasia), a **hybrid functional appliance** may be used to impede vertical dentoalveolar development on the affected side and permit selective dental overeruption on the unaffected side. This may help to limit the canting in the maxillary occlusal plane. Such appliances may also create a more favourable environment to encourage growth in conditions resulting in unilateral deficiency of condylar growth, such as hemifacial microsomia.

Conversely, most developmental asymmetries resulting in excessive growth, such as hemimandibular elongation, cannot be definitively treated until the cessation of growth, otherwise potential continued asymmetrical post-surgical growth would undo the benefits of corrective surgery. A number of diagnostic tools are available when it is necessary to evaluate the growth status of a patient. These are described below.

Superimposition of serial cephalometric images and other imaging modalities

The superimposition of successive lateral cephalometric radiographs of one individual provides an indication of overall craniofacial growth, particularly in terms of growth direction in the sagittal and vertical planes. *No region of the craniofacial skeleton can be considered absolutely stable during growth*, and therefore there is no perfect reference line for superimposition. As neurocranial growth is largely complete at the end of the seventh year of life the overall changes in facial pattern may be evaluated by *superimposition on the anterior cranial base*, which may be considered as relatively stable. Superimposition on the **SN line** with registration at sella provides a relatively reliable indication of overall facial growth, but is limited if upward or downward changes in nasion have occurred. An alternative and more reliable reference line is **De Coster's line**,¹⁹ which follows the outline of the internal surface of the anterior cranial base from the base and anterior wall of the sella turcica and the anterior clinoid process, along the planum sphenoidale (upper surface of the sphenoid bone) to the cranial aspect (roof) of the cribriform plate of the ethmoid and onto the endocranial surface of the frontal bone (Figure 10.39). *If the superimposition of two lateral cephalometric radiographs taken one year apart demonstrates no changes, this may be taken as a reliable indicator of growth cessation.*

It is possible to attempt the superimposition of serial PA cephalographs if great care is taken in ensuring standardization of technique. Comparison of serial OPTs provides an indication of asymmetrical changes in the mandibular ramus and body. Overall, comparison of measurements between recognized landmarks may be more accurate than superimposition for these images, mainly because there are no reliable stable reference structures.

Superimposition of serial 3D surface images provides an indication of changes in the facial soft tissues as a result of asymmetrical growth (Figure 10.40). Changes may be visualized



Figure 10.39 Superimposition of two lateral cephalometric radiographs taken three years apart (white: original); superimposition on the anterior cranial base (blue line representing De Coster's line).

by colour changes or dimension/volume changes. The difficulties of stable reference structures remain in using these imaging modalities.

Comparison of serial dental study models helps to evaluate occlusal changes resulting from asymmetrical jaw growth.

Growth prediction

'If you can look into the seeds of time,
And say which grain will grow and which will not,
Speak then to me.'

William Shakespeare, Macbeth (c. 1606)²⁰

There is considerable **individual variability** in the pattern of craniofacial growth. **Growth prediction** refers to the estimation of the magnitude and direction of craniofacial skeletal and soft tissue growth. Growth prediction is currently based on the 'normal growth changes' that have been documented from longitudinal serial cephalometric studies of 'normal' individuals in a number of growth studies. As such, growth prediction may be possible *to some extent* for individuals that are representative, in terms of sex and ethnicity, of the sample from which growth data are taken. Individuals with facial deformities are by definition

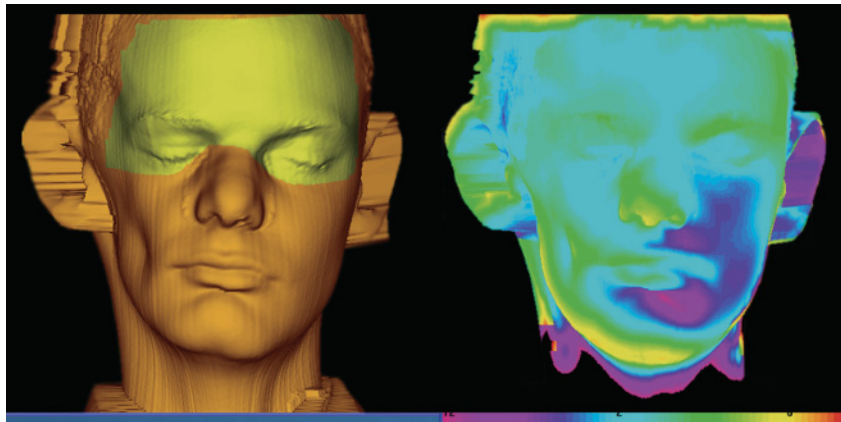


Figure 10.40 Superimposition of serial 3D surface images provides an indication of changes in the facial soft tissues as a result of asymmetrical growth; warm colours represent increasing convexity and cold colours represent increasing concavity.

‘not average’. However, *it is in these individuals for whom growth prediction would be most important that it is least reliable.*²¹ It is not possible to predict accurately the **magnitude** or **direction** of craniofacial growth, though once the **pattern of facial growth** has been established it is unlikely to significantly alter, e.g. if two serial lateral cephalographs demonstrate a skeletal Class III growth pattern, the pattern is unlikely to change.

Growth of the craniofacial complex tends to correlate well with growth in stature. **Serial standing height measurements** and the onset of **secondary sexual characteristics** may help to determine the onset of the **adolescent (pubertal) growth spurt** in younger patients and to provide an indication of **growth cessation** in preparation for orthognathic surgery, as growth in standing height is well correlated with jaw growth. Such information may be helpful in timing treatment and *assessing the potential for further craniofacial growth*, particularly when excessive.

Successive height measurements correlated to a patient’s age may be plotted on a height **growth chart**, which is compiled from extensive cross-sectional growth studies (Figure 10.41).²² Such charts show the mean height attained at each age, termed the **50th centile**, and also the centile lines for the 75th, 90th and 97th centiles, in addition to the 25th, 10th and 3rd centiles. A minimum of *three consecutive standing height measurements* are required to estimate with reasonable accuracy the growth curve that a particular patient may be following. The adolescent growth spurt may be expected at the age of:

- Boys: 14 ± 2 years (average duration: 2.5 years).
- Girls: 12 ± 2 years (average duration: 2 years).

These figures are variable, both within and between populations. Girls gain approximately 16 cm in height during the spurt, with a peak velocity at 12 years of age. Boys gain approximately 20 cm in height with a peak velocity at 14 years of age.

Nuclear medicine (scintigraphy)

The gamma-emitting, bone-seeking isotope ^{99m}Tc (technetium-99m) may be used to distinguish an active, rapidly growing condyle from the contralateral condyle in patients with asymmetrical mandibular growth due to unilateral condylar overgrowth. This short-lived isotope becomes concentrated in areas of active bone deposition, such as the alveolar ridges during the eruption of the teeth. The condyles are not normally areas of intense imaging and a ‘hot’ condyle is evidence of active condylar growth (Figure 10.42). This technique cannot by itself rule out excessive unilateral condylar growth as false negatives do occur. A negative scan means further investigation and observation of growth is required. However, false positive images are rare. Therefore, a positive unilateral condylar ‘hot spot’ is a good indication of excessive growth.

More recent and potentially useful advances in nuclear imaging include the use of single photon emission computed tomography (SPECT), which increases image contrast and improves lesion detection and localization.²³ The technique has demonstrated enhanced diagnostic accuracy for condylar hyperplasia and hemimandibular hyperplasia compared with conventional planar ^{99m}Tc scanning.²⁴

Note

Bone scanning is highly sensitive but non-specific. In patients where evidence of unilateral condylar hyperactivity is found, scintigraphy cannot define the cause, e.g. inflammation, malignancy, reparative process or growth activity. *The findings must match the clinical picture.* However, in cases of excessive unilateral condylar growth, the results of scintigraphy may help direct the treatment plan.²⁵

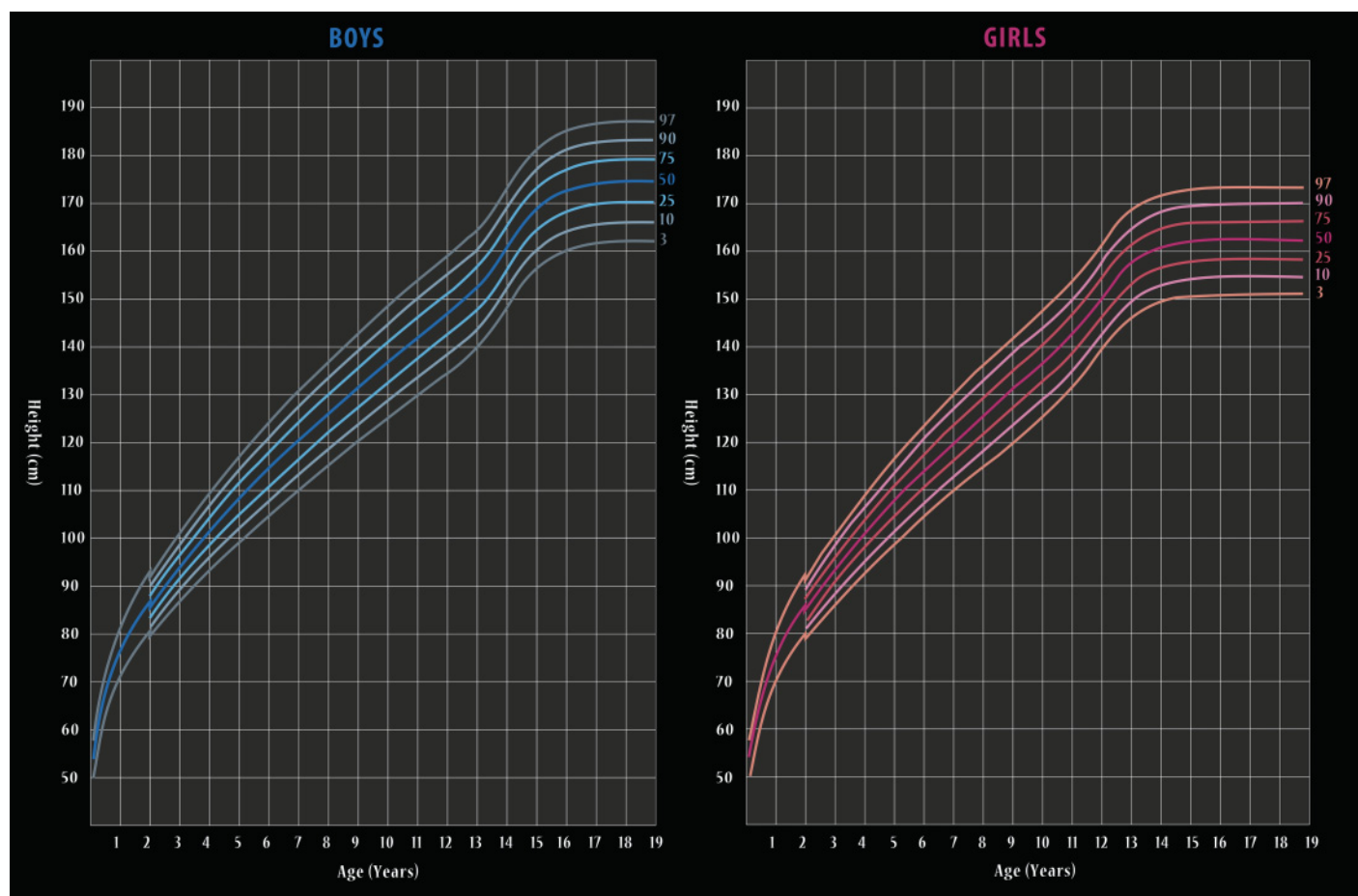


Figure 10.41 Standard growth charts (height); individuals at the midpoint of the normal distribution of the population follow the 50% line (50th centile); individuals taller than 90% of the population fall above the 90th centile whereas anyone shorter than 90% of the population falls below the 10th centile.

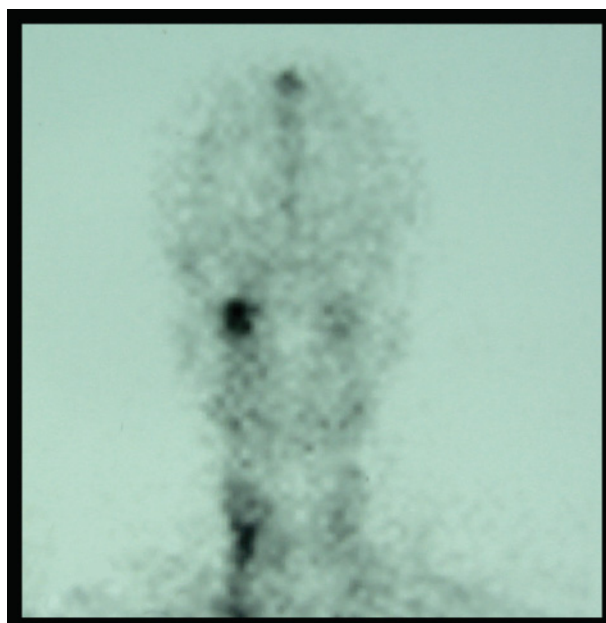


Figure 10.42 Skull and neck (posteroanterior view) scintigraph demonstrating a unilateral area of intense imaging ('hot' condyle), which is evidence of active condylar growth.

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SECTION 3 Facial Aesthetic Analysis: Regional Analysis

Introduction to Section 3

‘The true knowledge of the shape of any body will be arrived at by seeing it from different aspects.’¹

Leonardo da Vinci

At this stage the clinical evaluation of the *overall* craniofacial complex has been undertaken. The clinician will have a good idea about the facial type, the sagittal facial and jaw relationships, vertical and transverse facial proportional relationships, and the presence and extent of facial symmetry and asymmetry. The facial regions *at fault* will have been identified.

Note

For descriptive purposes the surface of the face may be divided into regions, or **units**. Each facial unit may be further subdivided into its component **subunits**. This concept is evident in the work of Albrecht Dürer, though Dürer used the term facial ‘facets’ (Figure S3.1) Gonzalez-Ulloa et al.² described these regional units as **aesthetic units**, which have distinct transition lines between them, e.g. the nose is an aesthetic unit of the face (Figure S3.2). Gonzalez-Ulloa et al.² felt that the reason for the transition lines between the various aesthetic units was the difference in the surface epithelium covering each unit. Each facial aesthetic unit is comprised of distinctive smaller component parts, referred to as **regional or topographic subunits**.³ This **subunit principle** is important in planning facial reconstructive surgery, e.g. placing incisions strategically at the subunit boundaries helps to camouflage the resultant scars.

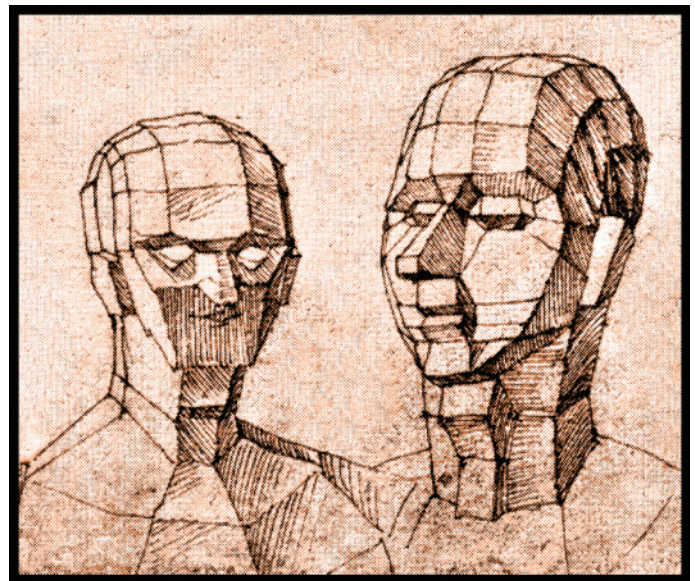


Figure S3.1 Heads Divided into Facets. (Detail, Albrecht Dürer, 1519, Sächsische Landesbibliothek, Dresden.)

The modified subunit principle

Following the overall yet comprehensive facial evaluation (Chapters 8–10), it is necessary to focus the clinical evaluation on the facial regions (or units) that are deemed to be at fault. A **modified subunit principle** may be used in the analysis and clinical diagnosis of facial deformities. As such, the facial soft tissue units and subunits are analysed in relation to their underlying dentoskeletal framework. In Section 3, each such region, or unit, will be described in a separate chapter (Chapters 11

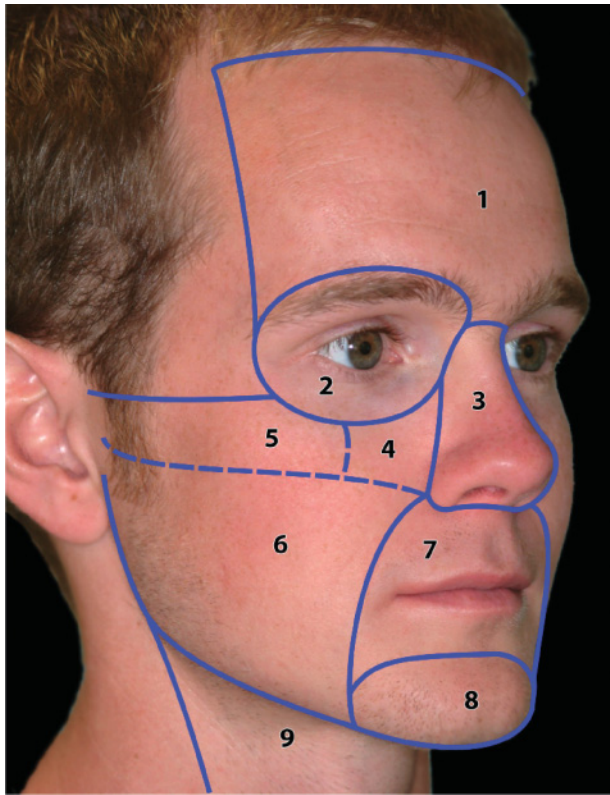


Figure S3.2 Facial soft tissue aesthetic units/regions:

- 1 Forehead unit
- 2 Orbital unit
- 3 Nasal unit
- 4 Infraorbital (sub)unit
- 5 Zygomatic (sub)unit
- 6 Cheek unit
- 7 Lip unit
- 8 Chin unit
- 9 Submental-cervical unit

Note There is some overlap between certain regions in terms of aesthetic analysis, e.g. the mentolabial region may be described as a distinct subunit of the lower face, but is intimately related both to the lower lip subunit and the chin unit.

to 21), using a 'top-down' approach, i.e. clinical evaluation and analysis working from the forehead region towards the submental-cervical region.

For each facial unit, and its constituent subunits, it is necessary to evaluate the following:

- **Relationship of hard to soft tissue components.**
- **Size:**
 - **Absolute size** – Measured in millimetres and compared with age-, sex- and ethnicity-specific normative standards.
 - **Relative size** – In relation to neighbouring facial units and the rest of the craniofacial complex; this proportional relationship is more important than any absolute

measurement, e.g. a large nose may be well proportioned in relation to a large craniofacial complex.

- **Shape/morphology.**
- **Relative position:**
 - In all three **planes of space:**
 - **Sagittal (anteroposterior) plane**
 - **Vertical plane**
 - **Transverse plane.**
 - Extent of **rotation about facial axes:**
 - **Sagittal axis**
 - **Vertical axis**
 - **Transverse (horizontal) axis.**
- **Growth, development and ageing:** It is always necessary to assess, as far as possible, the pattern of craniofacial growth, the likelihood and possible extent of further growth, soft tissue maturation and the effects of ageing.

Relativity and the five facial prominences

'When you are courting a nice girl, an hour seems like a second. When you sit on a red-hot cinder, a second seems like an hour. That's relativity.'

Albert Einstein (1879–1955), German-born theoretical physicist; founder of the theory of relativity. This was Einstein's explanation of his theory of relativity, given to his secretary to relay to reporters and other laypersons. Quoted in the *News Chronicle* (14 March, 1949)

Albert Einstein (Figure S3.3) is widely regarded as the greatest scientist of the twentieth century for his ability to not only think laterally, but actually invent new ways to think, ignoring how past thinkers viewed certain scientific concepts. As a genius he looked at the problems of theoretical physics in a unique way, moving existing understanding into new patterns, and finally seeing things that nobody else could.

Until Einstein's theory of relativity was put forward, scientific thinking had followed the ideals of **absolutism**. In science, tangible parameters were viewed in defined terms such as length or mass, which were 'absolute', e.g. a 100 cm line was 100 cm in length; there was no argument. However, Einstein's theory of relativity stated that the line was only 100 cm in length depending on a number of other factors, such as the relative motion of the observer and the observed object, in this case the 100 cm line. Therefore, *nothing was absolute, and everything was relative*. This theory altered European thinking in science, but its effects were far more widespread, influencing artists and writers such as Picasso and Proust.

The concept of relativity has a very special place in the clinical evaluation of craniofacial morphology. Every facial parameter has absolute dimensions, i.e. height, width, depth and volume. However, whether that parameter is perceived as proportionate or disproportionate, attractive or unattractive, depends on its

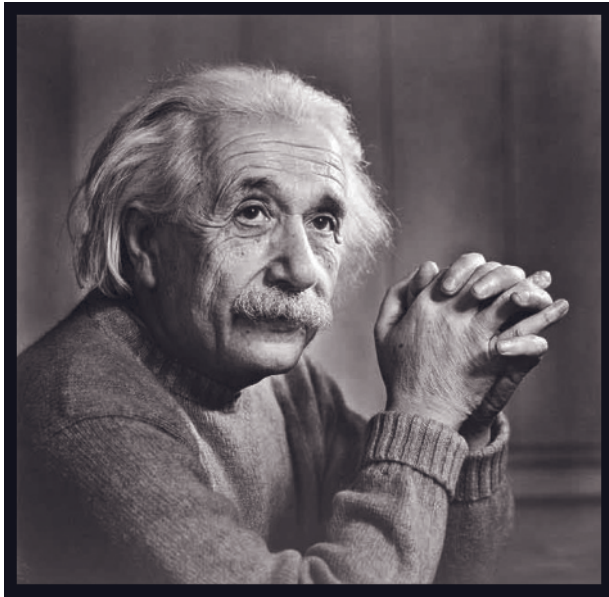


Figure S3.3 Albert Einstein (1879–1955).

relative size, shape and position in relation to its neighbouring structures and the entire craniofacial complex, i.e. *in facial aesthetics, everything is relative*.

The five facial profile prominences

It is important to evaluate each facial parameter, each facial aesthetic unit and its constituent subunits, in isolation; masking parts of the face with a piece of cardboard permits such evaluation. But, it is the relative interrelationships of the various facial units that are ultimately more significant in clinical diagnosis and treatment planning. As such, five facial prominences are apparent in profile view – the **forehead, nose, lips, chin** and **submental-cervical region** – and it is the relative interrelationship between these five prominences that provides the observed facial form.

The significance of each facial aesthetic unit on the aesthetic perception of the adjoining units is important. A patient may

have increased nasal projection compared with absolute values derived from population ‘norms’, but the nose may be perceived as proportionate if the lips and chin are also prominent. In 1958, Aufricht wrote:

‘The nose and the chin are conspicuous components of the profile line, and there is marked aesthetic interrelation between the two. The prominence of one will influence the relative prominence of the other.’⁴

Lack of forehead prominence will influence the perceived projection of the nose. A patient may have nasal and chin projection within normal limits compared with population norms, but the nose and chin will appear excessively prominent if the lips are retrusive. Therefore, the *outlining contour of each facial prominence will affect the perceived aesthetics of the others*. The closer each facial aesthetic unit is to the parameter deemed to be at fault, the greater its influence on the perceived appearance of that unit, e.g. the upper lip prominence has a significant effect on the perception of nasal projection, its neighbouring aesthetic unit.

Having undertaken a systematic, thorough and accurate clinical evaluation of the craniofacial complex, the clinician must consider the patient as a whole. The non-specific term ‘facial harmony’ refers to this proportional interrelationship of the various facial aesthetic units.

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Upper Facial Analysis

Chapter 11 The Forehead

Introduction and terminology

Throughout history a great many cultures have represented the forehead as the emblem of intelligence and high thought, presumably because behind it lie the frontal lobes of the brain, responsible for behaviour, learning and personality (Figure 11.1).

The forehead is the region of the face between the hairline and the eyebrows, formed by the smooth convexity of the frontal bone. The inferior aspect of the forehead merges seamlessly with the superior margin of each orbit. Just above each orbital margin is the variably prominent **superciliary arch**, alternatively termed the **brow ridge** or **supraorbital ridge**, which is usually more prominent in the adult male. These arches are united across the midline by another prominent ridge, the **glabella**. Beneath the superciliary arch on the frontal bone is the **supraorbital rim/arch/margin**, a curved and prominent margin that forms the upper boundary of the orbit and separates the vertical from the horizontal portion of the frontal bone (Figure 11.2).

The forehead is often an uneventful facial aesthetic unit; its inferior landmarks are commonly used as stable points from which to evaluate the relative position of mid and lower facial structures. However, patients with certain craniofacial syndromes, such as the craniosynostoses, may have considerable disproportion of the forehead region and cranium, which requires careful evaluation.

Anatomy

The **frontal bone** provides the skeletal framework for the upper facial third, occupying the upper third of the anterior view of the



Figure 11.1 Many cultures have represented the forehead as the emblem of intelligence and high thought. (Detail, *Portrait of a Lady* or *La Belle Ferronnière*, Leonardo da Vinci, c. 1496, Musée du Louvre, Paris.)

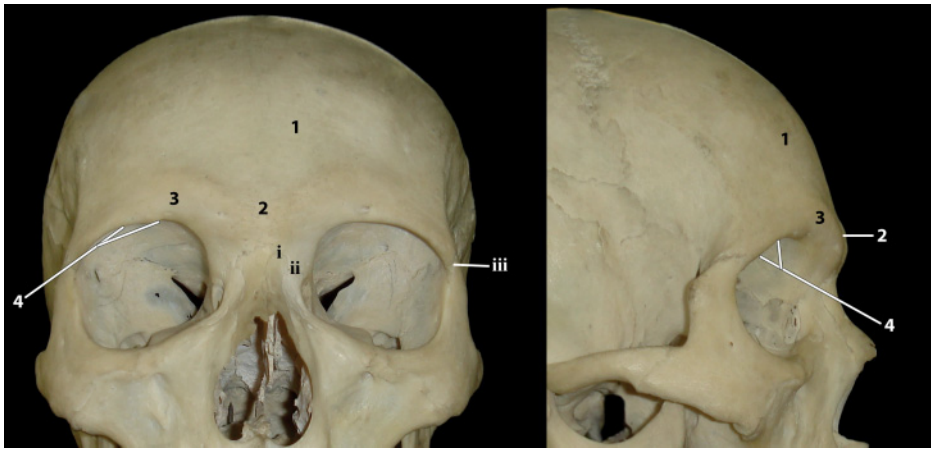


Figure 11.2 Forehead anatomy:

- 1 Squamous part of the frontal bone
- 2 Glabellar region
- 3 Supraorbital ridge (superciliary arch; brow ridge)
- 4 Supraorbital rim/margin
- i Frontonasal (nasofrontal) suture
- ii Frontomaxillary suture
- iii Frontozygomatic (FZ) suture

adult skull. The squamous part of the bone *curves* upwards and backwards from the upper margins of the orbits and nose. Medially its inferior border articulates with the frontal process of each maxilla, between which it articulates with the nasal bones. Laterally it projects down as a zygomatic process, articulating with the frontal process of the zygomatic bone, together forming the lateral margin of the orbit (Figure 11.2).

The supraorbital part of the frontal bone contains the two **frontal paranasal air sinuses**. These are irregularly shaped cavities which extend, to a variable extent, backwards into the roof of the orbit and upwards into the frontal region. They are separated from each other by a septum, which often deviates considerably from the median plane; as a result the two sinuses are frequently of unequal size. The *frontal air sinuses vary greatly in size and shape from one individual to another*. They are the only sinuses not present at birth; they appear during the second year of life, enlarge considerably during adolescence due to enlargement of the frontal bone and continue to grow, albeit more slowly and essentially by resorption of the surrounding cancellous bone, throughout adult life.

The prominence of the supraorbital ridge is variable, and often more pronounced in males than females.

Clinical evaluation

Clinical evaluation of the upper facial third is primarily concerned with the relative size, shape and degree of protrusion of the forehead. The forehead, which is the area from trichion (hairline) to and including the glabellar region, is considered as a single facial aesthetic unit, comprised of two subunits (Figure 11.3):¹

- **Superior forehead** subunit.
- **Supraorbital ridge-lateral orbital rim** subunit, which includes the glabellar region.

Note

The morphology, position and degree of protrusion of the supraorbital ridge-lateral orbital rim subunit is an important element in the aesthetic analysis of the forehead region.

Clinical evaluation is undertaken with the patient in natural head position and the forehead muscles in repose.

Frontal view

The lateral contour of the face, connecting the frontotemporale point of the forehead with the gonion of the mandible, has a relatively specific outline.² This *outer contour* of the face is due to the proportional relationship between the upper (forehead), middle and lower facial widths (Figure 11.4).

Forehead width

The **bizygomatic distance** should be the widest part of the face. **Bitemporal width**, measured from the most lateral point on each side of the forehead (frontotemporale, Ft), is 80–85% of bizygomatic width. **Bigonial width**, measured from the soft tissue overlying the most lateral point of each mandibular angle (soft tissue gonion, Go'), is usually 70–75% of bizygomatic width (see Figure 8.4).

Note

In frontal view, the *perceived* width of the forehead is influenced by the width of the rest of the face, i.e. bizygomatic and bigonial widths. If a patient has a narrow mid and lower face, even a normal forehead will appear wide. Therefore, the *relative* width of the forehead is more important than the absolute width.

Forehead height

The average height of the forehead (trichion to glabella) in adult Caucasians is:³

- Male: 57 ± 7 mm.
- Female: 53 ± 6 mm.

Proportionally, the height of the forehead should be approximately one-third of total face height (trichion to soft tissue menton). The forehead thus represents the upper third of the Vitruvian facial trisection (see Figures 9.13 and 9.14). Based on modern anthropometric measurements, Farkas³ found that the

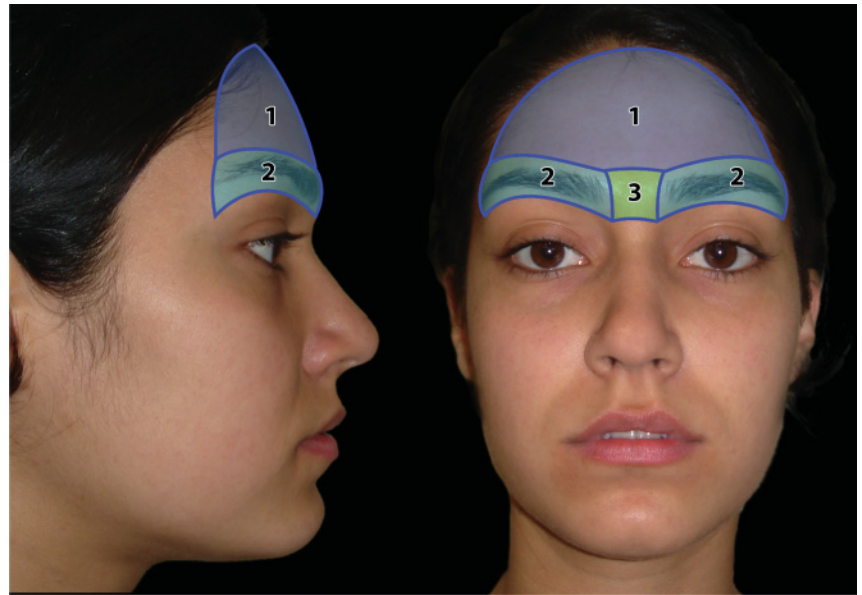


Figure 11.3 The forehead aesthetic unit is comprised of two subunits:

- 1 Superior forehead subunit – this consists of the soft tissue and underlying squamous part of the frontal bone
- 2 Supraorbital ridge-lateral orbital rim subunit, which includes the glabellar region (3).

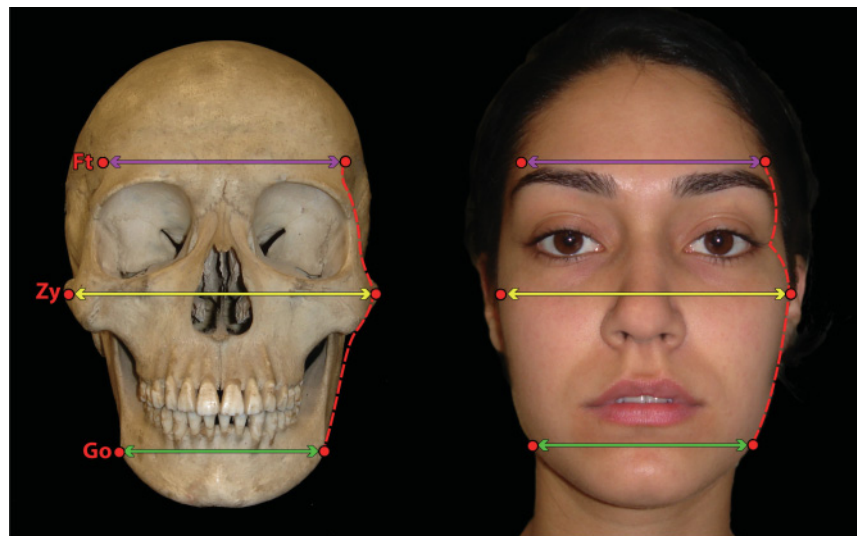


Figure 11.4 The outer contour of the face (lateral facial contour in frontal view) is due to the proportional relationship between the upper (forehead), middle (bizygomatic) and lower (bigonial) facial widths. Ft, frontotemporal; Zy, zygion; Go, gonion.

forehead height is on average 9 mm less than the midfacial height and 18 mm less than lower anterior face height.

Note

The hairline defines the superior boundary of the forehead, with its midline point termed trichion. The male hairline is often higher than the female and tends to have an 'M' shape that recedes at the temples. In patients with **receding hairlines**, trichion may be located by instructing the patient to raise their eyebrows. The superior aspect of the contraction of the frontalis muscle indicates the position of trichion (see Figure 6.18).

Profile view

The morphology of the forehead in profile view has a gentle convexity. Variations in forehead shape may be described as

protrusive, flat, posteriorly or anteriorly inclined. Excessive variation will result in visible disproportion.

Forehead inclination

The **forehead inclination**, also termed the **forehead slope**, refers to the *inclination of the anterior surface of the superior forehead subunit* observed in profile view, measured relative to a true vertical plane through glabella (Figure 11.5). The normal adult forehead has a mild posterior inclination:⁴

- Male: $10^\circ \pm 4^\circ$.
- Female: $6^\circ \pm 5^\circ$.

Note

The female forehead tends to be more vertical, whereas the male forehead has a relatively greater posterior inclination.



Figure 11.5 Forehead inclination may be mildly posterior (usually in men), almost vertical (usually women) or anterior.

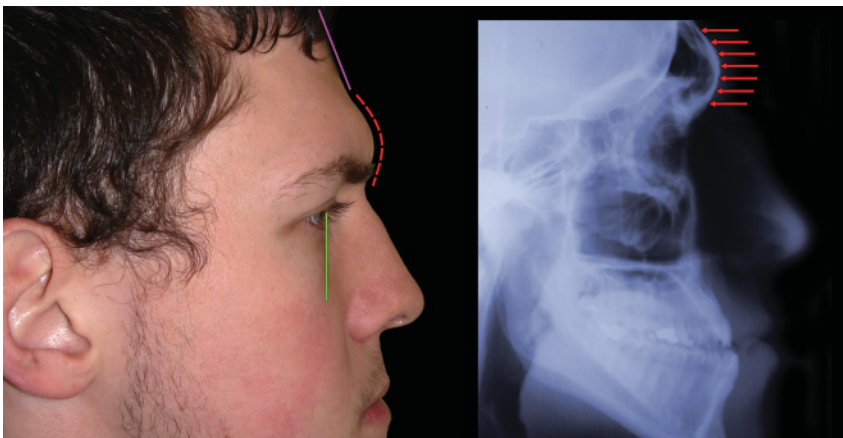


Figure 11.6 Frontal bossing is said to exist when the sagittal projection of the supraorbital rim is excessive relative to the anterior projection of the globe and/or the inclination of the superior forehead subunit. The aetiology here is enlargement of the frontal sinus.

Supraorbital rim projection

The supraorbital rims laterally and the glabella medially are the most projected areas of the forehead. Supraorbital rim projection may be evaluated in relation to the globes. The supraorbital rims will normally project 5–10mm beyond the anterior corneal plane.⁵

Variations in the shape and position of the supraorbital rims may result in:

- **Frontal bossing:** This is said to exist when the *sagittal projection of the supraorbital rim is excessive* relative to the anterior projection of the globe and/or the inclination of the superior forehead subunit (Figure 11.6). Excessive posterior inclination of the superior forehead subunit will result in the appearance of frontal bossing.

Note

Frontal bossing may occasionally be related to excessive subcutaneous adipose tissue. It is important to palpate the supraorbital rim region and assess the radiographic appearance in order to accurately ascertain the aetiology of frontal bossing.⁶

- **Supraorbital rim deficiency (hypoplasia):** This exists when the supraorbital rims do not project adequately in relation to the globes.

Note

If the forehead is excessively protrusive, the supraorbital rims will appear deficient.

Morphology of the glabellar-nasal radix region

The relative position of nasion to glabella will affect the *perceived* projection of the glabellar region, and may be evaluated by assessment of two variables:

- **Sagittal position of nasion:** Normally, nasion is approximately 4–6 mm posterior to glabella in profile view (see Chapter 14).
- **Nasofrontal angle:** The nasofrontal (or glabellar) angle is the anterior angle formed by the intersection of the glabella-nasion line and the nasal dorsum tangent. An increased angle implies supraorbital rim deficiency and/or a depressed nasal dorsum. The angle may be separated into upper and lower components with a true horizontal line through soft tissue nasion (Figure 11.7). Normal values are:⁴
 - Male: $130^{\circ} \pm 7^{\circ}$.
 - Female: $134^{\circ} \pm 7^{\circ}$.

Note

Powell and Humphreys suggested the nasofrontal angle should be in the range of 125° – 135° for 'ideal' aesthetics.⁷

Superior view

When viewed from above, the supraorbital ridge should arc posteriorly to achieve a gentle 90° angle at the temporal fossa, with the central point of the arc at the level of the frontozygomatic suture region.¹

Curvilinear relationships

The convex outer contour of the superior forehead subunit is curvilinear in all dimensions, though very slightly flattened (more in the female) in the lower mid portion (Figure 11.8).

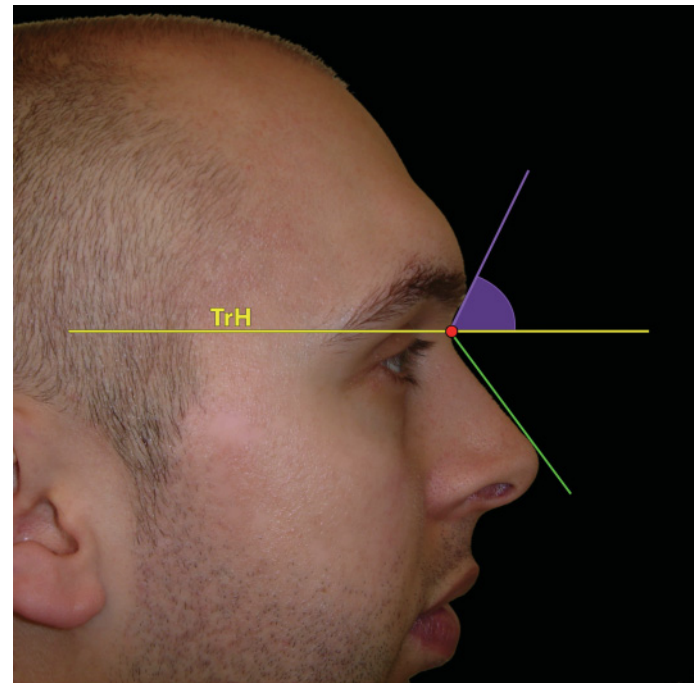


Figure 11.7 The nasofrontal (or glabellar) angle may be separated into upper and lower components by a true horizontal line through soft tissue nasion; a reduced angle (upper component) will thereby imply excessive supraorbital ridge projection.

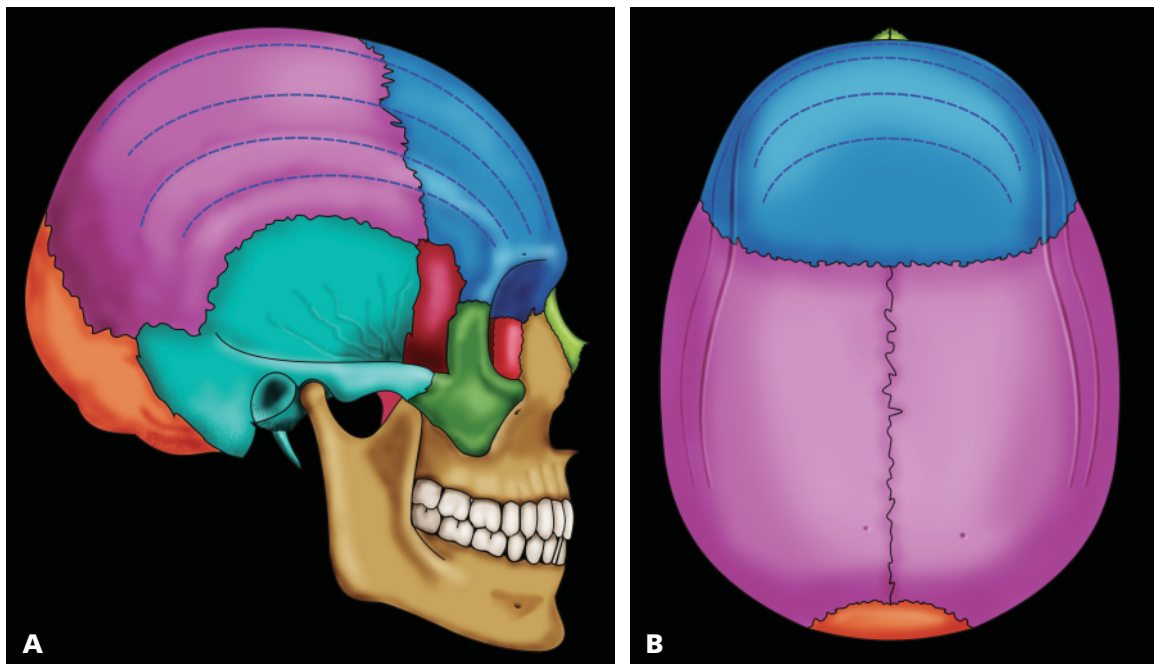


Figure 11.8 The convex outer contour of the superior forehead subunit is curvilinear in all dimensions: (A) lateral view; (B) superior view. These curvilinear relationships of the frontal bone and cranium are evident in the overlying soft tissue contour of the forehead.

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Chapter 12 The Orbital Region

Introduction

‘If I could write the beauty of your eyes
And in fresh numbers number all your graces,
The age to come would say, “This poet lies;
Such heavenly touches ne’er touch’d earthly faces”.’

William Shakespeare, extract from Sonnet XVII¹

The above extract from Shakespeare’s Sonnet XVII proves two things: firstly, the genius of William Shakespeare, and secondly, the importance of the eyes in facial aesthetics. Perhaps more has been written about the beauty of the eyes than any other facial feature.

The **orbital region**, composed of the visible eye, eyelids and eyebrow, forms an important facial aesthetic unit, crucial to an attractive appearance and vital for communication through facial expression (Figure 12.1).

The eyes

The **eyes** convey thought. The Roman philosopher Cicero (106–43 BC) is quoted as saying, ‘The face is a picture of the mind as the eyes are its interpreter.’² This formed the basis of the Latin proverb: ‘The face is the index of the mind’. The Bible says: ‘The light of the body is the eye.’³ The Roman scholar Pliny the Elder (c. AD 23–79) wrote: ‘The eyes are the window to the soul’,⁴ a phrase made famous by Leonardo da Vinci: ‘The eye, which is called the window of the soul, is the chief means whereby the understanding may most fully and abundantly appreciate the infinite works of nature.’⁵

Image not available in the electronic edition

Figure 12.1 The eyes are arguably the most important facial aesthetic feature. (Detail, the angel from *Madonna of the Rocks*, Leonardo da Vinci, c. 1495–1508, National Gallery, London.) (Copyright ©1995 National Gallery, London. All rights reserved. Reprinted by permission.)

The scholar Saint Jerome (AD 342–420) wrote: ‘The face is the mirror of the mind, and eyes without speaking confess the secrets of the heart’; this formed the basis of the French proverb: ‘The eyes are the mirror of the soul.’⁶ Charlotte Brontë’s *Jane Eyre* (1847) says: ‘The soul, fortunately, has an interpreter – often an unconscious but still a faithful interpreter – in the eye.’⁷

The eyes are also magnificently expressive. In his encyclopaedia entitled *Historia Naturalis*, Pliny the Elder wrote: ‘No other part of the body supplies more evidence of the state of mind.’⁴ The universality of the expressiveness of the eyes is also alluded to by the English poet George Herbert (1593–1633) who wrote: ‘The eyes have one language everywhere.’⁸ In *Don Quixote*, the Spanish author Miguel de Cervantes (1547–1616) supported this concept with the character Antonio’s amorous complaint: ‘The eyes those silent tongues of love.’⁹

When the *Beagle* docked in Peru, Charles Darwin described the women as shrouded in veils that only left one eye exposed, yet he felt this eye to be supremely expressive. ‘But then,’ he wrote, ‘that one eye is so black and brilliant and has such powers of motion and expression that its effect is very powerful.’¹⁰

Eyebrows

‘Her eyes like angels watch them still;
Her brows like bended bows do stand ...’

Thomas Campion (1567–1620), English poet and physician, *Cherry-Ripe*¹¹

The function of the **eyebrows** is to act as umbrellas for the eyes; Cicero explained that the eyebrows prevent forehead perspiration from falling into the eyes.² Yet eyebrow shape and position has a profound influence on communication by way of facial expression. Simply raising or lowering the medial brow reflects a change in expression from surprise to anger (see Chapter 3).

‘The eyebrows form but a small part of the face, and yet they can darken the whole of life by the scorn they express,’ said the Athenian orator Demetrius (350–280 BC).

The importance of the orbital and periorbital region, including the eyes, eyelids, eyelashes and eyebrows, cannot be underestimated in facial aesthetic analysis.

- Entropion: Abnormal inward rolling of the eyelid against the eyeball, resulting in irritation of the cornea by the eyelashes (trichiasis).
- Exophthalmos: Abnormal protrusion of the eyeball.
- Iris (Greek: the rainbow).
- Limbus (Latin: *border*), e.g. the medial iris limbus is the medial border of the iris.
- Ocular/ophthalmic/optic: relating to the eye.
- Sclera (from Greek *skleros*: ‘hard’); due to the density of the fibrous tissue that forms the outer covering of the eyeball.

Note

The term ‘brow’ refers to the forehead, e.g. ‘she wiped her brow’; whereas, the term ‘brows’ refers to the eyebrows. However, in clinical practice the term ‘brow’ is often used as a shortened version of eyebrow.

Anatomy

The **orbit** is a bony cavity shaped like a pyramid tilted on to one side, with the apex at the back and the base forming the

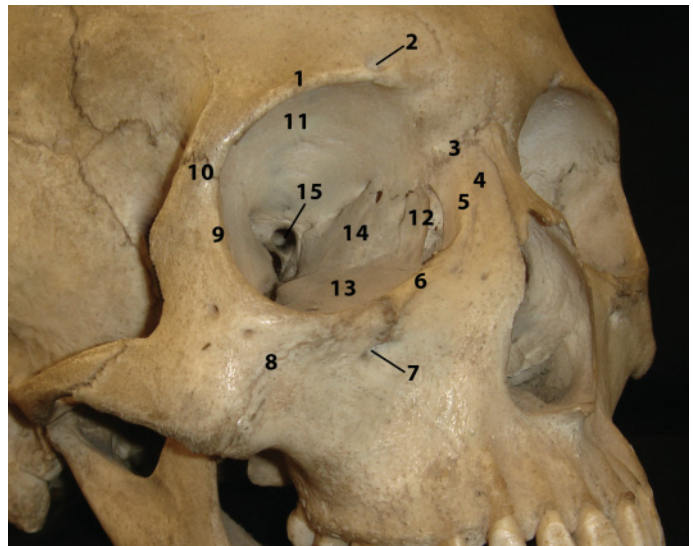


Figure 12.2 Orbital anatomy:

- 1 Superior orbital rim
- 2 Supraorbital foramen
- 3 Frontomaxillary suture
- 4 Frontal process of maxilla
- 5 Medial orbital rim
- 6 Inferior orbital rim
- 7 Infraorbital foramen
- 8 Zygomaticomaxillary suture
- 9 Lateral orbital rim
- 10 Frontozygomatic suture
- 11 Orbital part of frontal bone
- 12 Lacrimal bone
- 13 Orbital part of maxilla
- 14 Orbital plate of ethmoid bone
- 15 Optic canal

Terminology

- Blepharo- (from Greek *blefaron*: ‘eyelid’), e.g. ‘blepharoplasty’ refers to the ‘eyelid lift’ procedure.
- Chalasis (Greek, ‘relaxation’), e.g. ‘dermatochalasis’ of eyelid region refers to excess eyelid skin, particularly affecting the upper eyelid in ageing; ‘blepharochalasis’ suggests an inflammatory component to redundant eyelid skin.
- Canthus (from Greek *kanthos*: ‘the corner of the eye’).
- Ectropion: Abnormal eversion of the eyelid margin from the eyeball (globe); more common in lower eyelid; (from Greek *ek*- ‘out’ + *trepein* ‘to turn’).
- Enophthalmos: Abnormal retrusion of the eyeball into the orbit.

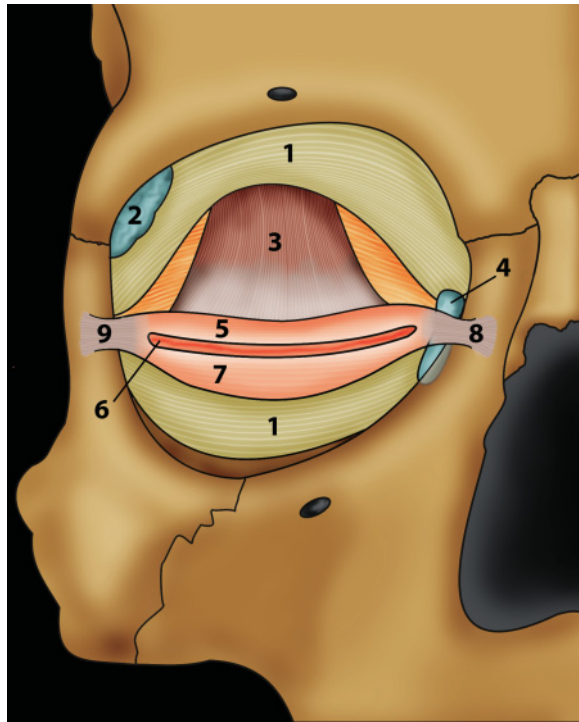


Figure 12.3 Eyelid anatomy: the tarsal plates, palpebral ligaments and orbital septum of the right eye:

- 1 Orbital septum
- 2 Lacrimal gland
- 3 Levator palpebrae superioris muscle and tendon
- 4 Lacrimal sac
- 5 Superior tarsal plate (superior tarsus)
- 6 Palpebral fissure
- 7 Inferior tarsal plate (inferior tarsus)
- 8 Medial palpebral ligament
- 9 Lateral palpebral ligament

opening on the front of the facial skeleton (Figure 12.2). This pyramid-shaped orbital cavity contains the eye, which is the organ of vision, and various accessory ocular structures, including the extraocular muscles which move the eye, the eyelids, conjunctiva, part of the lacrimal gland, and orbital fat, which fills the spaces in the orbit, surrounding the optic nerve and stabilizing and cushioning the eye.

The **eyelids (palpebrae)** are two thin moveable folds that cover the anterior surface of the eye (Figure 12.3). By their closure, they function to protect the eye from trauma or excessive light. The act of **blinking**, which occurs roughly 15 times per minute, maintains a thin film of tears over the cornea. The eyelids are covered in front with loose skin and behind with adherent **conjunctiva**, a transparent mucous membrane that covers the internal palpebral surfaces and is reflected over the sclera, where its epithelium becomes continuous with that of the cornea. The skeletal framework of the eyelids is formed by the orbital septum. This is thickened at the margins of the lids to form the **superior and inferior tarsal plates**, which are formed of dense fibrous tissue. The orbital septum has a separation between the two lids: the **palpebral fissure**. The medial and

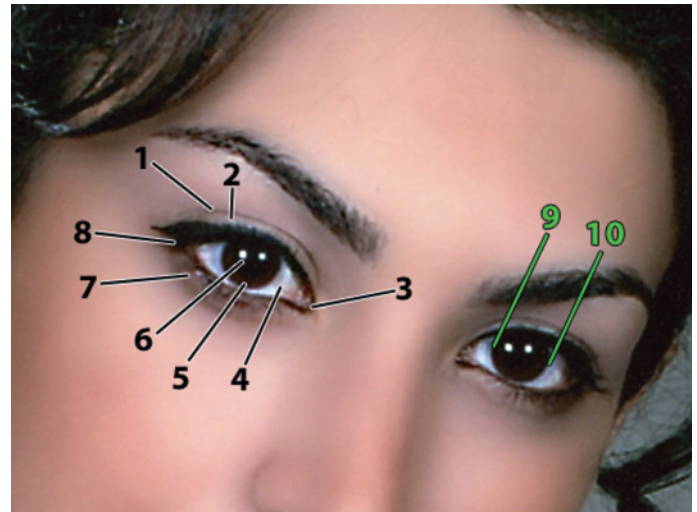


Figure 12.4 The eyes and eyelids (surface features):

- 1 Superior orbital fold (upper eyelid crease)
- 2 Upper eyelid
- 3 Medial canthus
- 4 Sclera with overlying conjunctiva
- 5 Iris
- 6 Pupil
- 7 Lower eyelid
- 8 Lateral canthus
- 9 Medial limbus (sclerocorneal junction)
- 10 Lateral limbus (sclerocorneal junction)

lateral palpebral ligaments anchor the tarsal plates to the anterior lacrimal crest and the marginal tubercle of the zygomatic bone, respectively. The medial commissure where the upper and lower lids meet is the **medial canthus**; laterally it is the **lateral canthus**. The skin overlying the eyelids is thin and densely adherent to the margins of the palpebral fissure; here, just outside the margin, are the **eyelashes**, short hairs whose follicles are stabilized by being attached to the rigid tarsal plates. The upper eyelashes curve upwards and the lower curve down so that upper and lower lashes do not intertwine when the lids are closed.

The **visible eye** is about one-sixth of the entire **eyeball (or globe)**, and its special attraction is partly due to the characteristic arrangement of its three interacting components: the white **sclera**, the coloured **iris** and the black **pupil** (Figure 12.4). The white colour of the exposed sclera is important as it contrasts with the darker iris and pupil, highlighting eye movement, which is *vital for communication*.

Surrounding the pupil is the iris, an adjustable diaphragm whose contraction and relaxation leads to pupillary constriction and dilatation, thereby controlling the amount of light entering the eye; pupillary diameter may vary from 1 mm to at least 8 mm. Alteration in the diameter of the pupil also occurs as an emotional response. The layperson term 'eye colour' refers to iris pigmentation, which is genetically determined. The iris is named after the rainbow, though its range of colour extends only from light blue to very dark brown. The colour may vary between the two eyes and even within the same iris. The distribution of

pigment is often irregular, producing a flecked appearance. Each iris pattern is unique, much like fingerprints, permitting iris recognition systems to identify individuals.

The transparent convex anterior portion of the outer fibrous covering of the eyeball is termed the **cornea**, which covers the iris and pupil and is continuous with the sclera.

Clinical evaluation

The patient should be examined in natural head position, with the eyebrows and forehead in repose.

Eyebrow position and contour

The position of the eyebrow is vitally important in the evaluation of the periorbital region and is undertaken *before* evaluation of the eyelids. There is considerable individual variation in the position and contour of the eyebrows. The 'ideal' **male eyebrow** is positioned on or close to the supraorbital rim and is essentially horizontal, or mildly arched in orientation, whereas the **female eyebrow** is positioned above the supraorbital rim and is shaped as a gentle arc.¹² The female lateral brow is positioned up to 10 mm superior to the supraorbital rim; the medial brow is usually 2 mm inferior to the lateral brow. The medial and central portions of the eyebrow are wider than the lateral portion.

The medial brow starts approximately above the medial canthus. In women, the highest point or **peak of the eyebrow arc** should be level with the lateral canthus, but may be anywhere between the lateral limbus and lateral canthus of the eye (Figure 12.5). Leonardo da Vinci described a diagonal line, extending from the oral commissure (angle of the mouth) tangent to the ipsilateral lateral limbus; the extension of this line designates the peak of the eyebrow (Leonardo's **commissure-limbus-eyebrow peak line**) (Figure 12.6). The medial curvature of the eyebrow

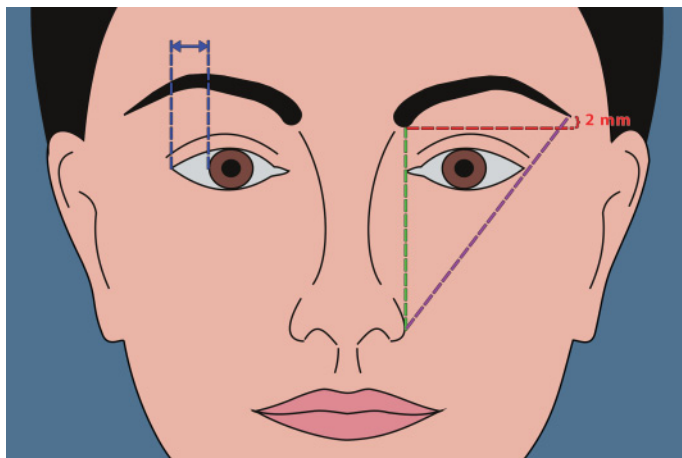


Figure 12.5 Eyebrow aesthetics: The medial brow starts approximately above the medial canthus. In women, the peak of the eyebrow arc may be anywhere between the lateral limbus and lateral canthus of the eye. The lateral most part of the female eyebrow is on a line tangent to the lateral canthus from the nasal ala and approximately 2 mm superior to the medial most part of the eyebrow.

continues with a smooth transition onto the aesthetic dorsal line of the nose; this curvilinear relationship is termed the **brow-nasal tip aesthetic line** (Figure 12.7). In men, the brow-nasal tip aesthetic line is more angular, in the form of an inverted 'L'.

Ptosis of the eyebrows may occur as a consequence of ageing or the inappropriate use of botulinum toxin type A. Ptosis of the medial eyebrow imparts an expression of anger, whereas ptosis of the lateral eyebrow conveys an expression of sadness. Ptosis of the entire eyebrow gives an aged and 'exhausted' appearance.

Orientation of palpebral fissure (Figure 12.8)

In the normal Caucasian eye, the medial canthus is about 2 mm lower than the lateral canthus; this distance is increased in some Far Eastern ethnic groups. The inclination of the palpebral fissure is:¹³

- Male: $2^\circ \pm 2^\circ$.
- Female: $4^\circ \pm 2^\circ$.

An increase in this inferomedial orientation of the **intercanthal axis** (horizontal axis of the eye) is termed a 'mongoloid' slant; conversely, if the lateral canthus is inferior to the medial canthus, it is termed an 'antimongoloid' slant (Figure 12.9). However, it is preferable to avoid these terms and simply describe the orientation of the palpebral fissure and intercanthal axis, e.g. increased inferomedial slant or increased inferolateral slant. The left and



Figure 12.6 Leonardo's commissure-limbus-eyebrow peak line. (Detail, *Study of Proportions of the Face, Eyes and Eyebrows*, Leonardo da Vinci, c. 1490, Biblioteca Reale, Turin.)

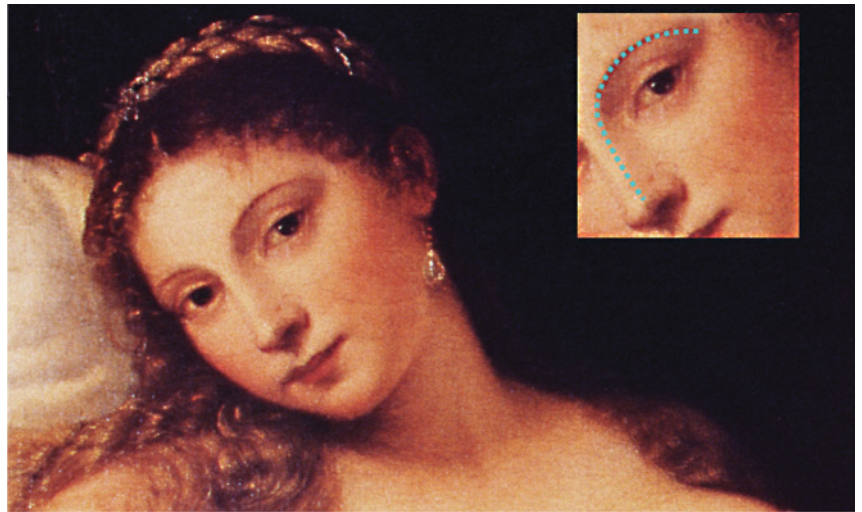


Figure 12.7 Brow-nasal tip aesthetic line. (Detail, *Venus of Urbino*, Titian, c. 1538, Galleria degli Uffizi, Florence.)



Figure 12.8 Orientation of palpebral fissure: In the normal Caucasian eye, the medial canthus is about 2 mm lower than the lateral canthus, with a mild inferomedial orientation of the intercanthal axis (horizontal axis of the eye).

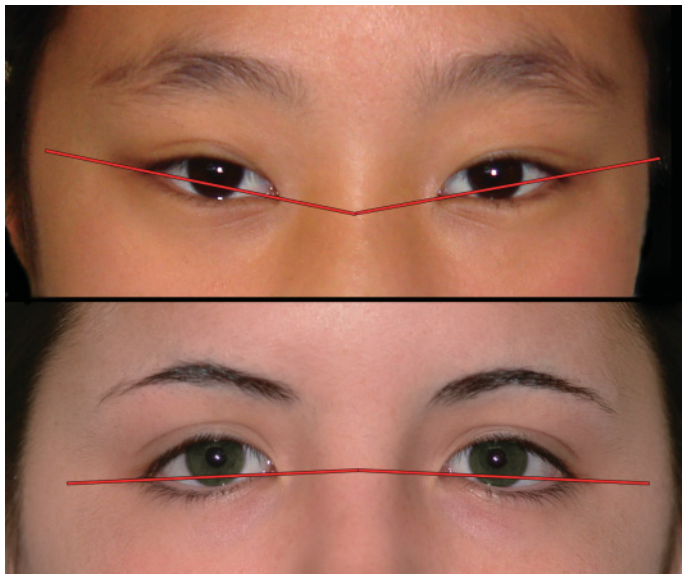


Figure 12.9 Increased inferomedial slant and increased inferolateral slant of the intercanthal axis.

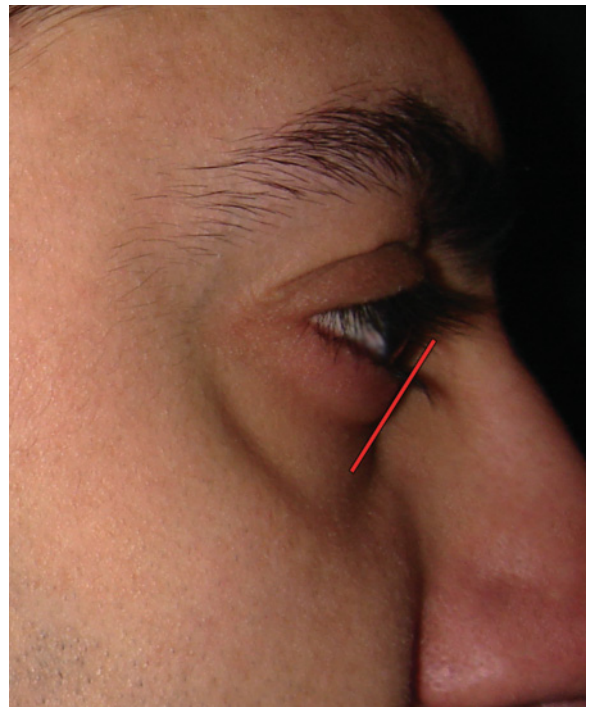


Figure 12.10 The lower eyelid lies on an inferior-posterior slope of approximately 45° from the upper lid in profile view.

right intercanthal axes should cross in the midline over the nasal dorsum; if they do not meet in the midline, this may be a sign of asymmetry.

Eyelids (palpebrae)

The eyelids cover the exposed anterior projection of the eyeball.

Eyelid shape

The upper lid is larger, more curved and rather more active than the lower.¹⁴ The lower lid lies on a backward slope of approximately 45° from the upper lid in profile view (Figure 12.10).

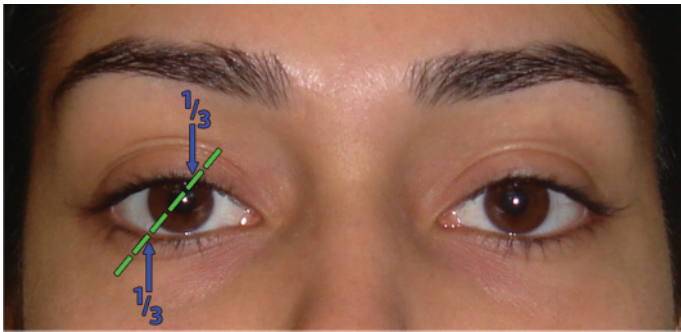


Figure 12.11 The superior most point of the curve of the upper lid margin and the inferior most point of the gently arcing lower lid margin.

The superior most point of the curve of the upper lid margin is approximately one-third of an eye width from the medial canthus. The inferior most point of the gently arcing lower lid margin lies between the pupil and lateral limbus, approximately one-third of an eye width from the lateral canthus (Figure 12.11).

The upper eyelid margin overlaps the superior iris limbus by 1–2 mm. There should be minimal or no scleral exposure between the lower lid margin and the inferior limbus; excessive scleral exposure below the iris is a sign of midfacial hypoplasia.

Eyelid tonicity

The lower eyelid should be taut against the globe. The most common cause of post-blepharoplasty lower lid ectropion is failure to recognize lower eyelid laxity prior to surgery. Two clinical tests are used to evaluate lower lid tone:¹⁵

- **Lid distraction test:** Using the thumb and index finger the clinician may gently pull the lower lid away from the globe and observe the rate of its return to a normal position against the globe on release; this 'snap back' test is helpful in determining lower lid tone and laxity. Excessive outward displacement of the eyelid from the globe and a slow rate of return indicate abnormal laxity.
- **Lid retraction test:** The clinician uses the index finger to gently inferiorly displace the lower lid. On release, the eyelid should return to its resting position immediately; a slow return indicates reduced lid tone and laxity of the canthal tendons.

Upper lid crease (superior palpebral fold; supratarsal fold)

The upper lid crease should be well defined and essentially parallel to the upper lid margin, and does not extend beyond the medial and lateral canthi. It normally divides the upper lid into an **inferior tarsal portion** (lower one-third) and a **superior septal portion** (upper two-thirds) (Figure 12.12). The upper lid crease may be absent in Far Eastern patients (Figure 12.13), and with ageing may become concealed behind redundant, ptotic skin (dermatochalasis). Lateral extension of the upper lid crease

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Figure 12.12 The upper lid crease normally divides the upper lid into an inferior tarsal portion (lower one-third) and a superior septal portion (upper two-thirds). (Detail, *Young Woman's Head*, Leonardo da Vinci, c. 1490, Royal Library, Windsor.) (With kind permission from The Royal Collection © 2010 Her Majesty Queen Elizabeth II.)



Figure 12.13 The upper lid crease may be absent in Far Eastern patients.

down over the eyelid and onto the lateral periorbital region is a sign of forehead ptosis, described as **Connell's sign**. A useful guideline is to maintain a distance of approximately 15 mm between the eyebrow and the upper lid crease.¹⁶ The vertical position of the upper lid crease may be evaluated by **Sheen's test** (lid margin to crease test) (Figure 12.14): the clinician elevates the eyebrow just enough to retract the excessive skin as the patient looks down at a 45° angle; the normal range of the distance from the central upper lid margin to the lid crease in white Caucasians should be 7–10 mm.¹⁷

Orbital fat

The orbital fat pads lie deep to the orbital septum. Laxity of the septum may lead to bulging of the fat, termed **prolapsed fat pads**, often seen in ageing eyelids. Observation and gentle palpation should be undertaken with the patient supine in order to avoid retrusion of the fat into the orbital cavity.

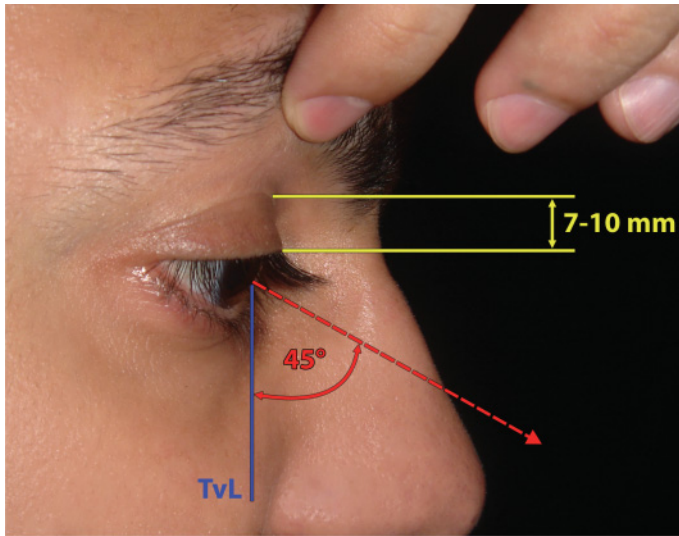


Figure 12.14 Sheen's test: the patient assumes a 45° downward gaze while the eyebrow is elevated just enough to retract the excessive skin. This manoeuvre should demonstrate the upper lid crease to be at least 7 mm from the central upper lid margin. TVL, true vertical line.

Eye width and interocular dimensions

Absolute measurements of the eyes and interocular dimensions will vary depending on age, sex and ethnic background. Significant abnormalities in these dimensions may occur in congenital craniofacial abnormalities and certain syndromic conditions.

Correction of such conditions requires complex craniofacial surgery, which may only be undertaken if deemed necessary to improve the patient's quality of life. The terminology described below may be employed (see Figure 9.26).

Telecanthus

An increased distance between the medial canthi of the eyelids; commonly found in Down syndrome.

Note

The distance between the medial canthi is a soft tissue measurement.

Orbital hypertelorism

An increased distance between the medial orbital walls, reflecting an increased distance between the orbits, greater than two standard deviations from the norm; found in a number of craniofacial syndromes, such as Crouzon or Apert syndrome (Figure 12.15).



Figure 12.15 Orbital hypertelorism in a patient with Crouzon syndrome.

Note

The distance between the medial orbital walls is a skeletal measurement.¹⁸

Orbital hypotelorism

A decreased distance between the medial orbital walls; very rare.

Normal values

Normative values for orbital and interocular dimensions have been provided by Farkas¹³ (Table 12.1) (Figure 12.16).

Proportional relationships of the orbital region

The **proportional relationships** of the orbital region are:

- According to the 'rule of fifths', the 'ideal' face may be transversely divided into five equal parts, each roughly equal to one eye width. The intercanthal distance is approximately equal to one eye width. The outer canthal distance is approximately equal to three eye widths (see Figure 9.25).
- The distance between the right and left medial limbus should be roughly equal to mouth width.
- The intercanthal width should be roughly equal to the alar base width.

Table 12.1 Normative values for orbital and interocular dimensions (see Figure 12.16)

Intercanthal width (En-En), mm		Interpupillary width, mm		Outer canthal width (Ex-Ex), mm		Eye fissure width (Ex-En), mm	
Male	Female	Male	Female	Male	Female	Male	Female
33 ± 2	32 ± 2	~65	~65	91 ± 3	88 ± 3	31 ± 1	31 ± 1

Data from Farkas¹³, except interpupillary width.¹⁹
Ex, exocanthion; En, endocanthion.

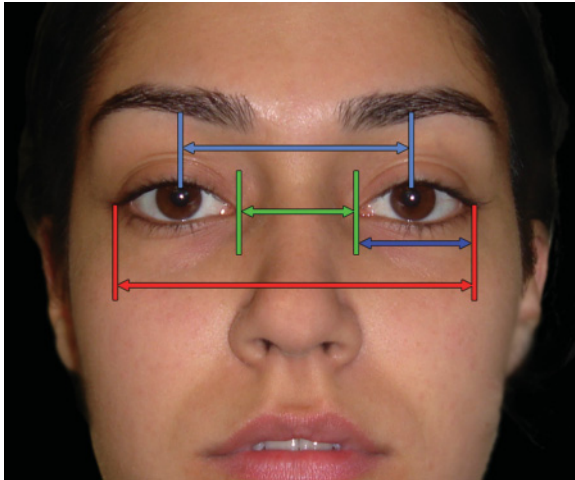


Figure 12.16 Orbital and interocular dimensions (for normative values see Table 12.1). Green line: intercanthal width; light blue line: interpupillary width; red line: outer canthal width; dark blue line: eye fissure width.

- Interpupillary distance is approximately equal to the distance from nasion to the upper mucocutaneous junction of the upper lip (labrale superius).

Relationship of bony orbit and globe

It is important to evaluate the relative position of the globe to its surrounding skeletal structures, particularly the orbital rims (see Figure 16.6):²⁰

- The supraorbital rim projects 8–10 mm beyond the cornea; men tend to have greater supraorbital rim projection than women.
- The cornea projects 2–3 mm beyond the inferior orbital rim.
- The cornea projects 12–16 mm beyond the lateral orbital rim.

Symmetry

Mild left-right asymmetry in the orbital and periorbital region is relatively common, but the presence of marked asymmetry in the orbital and periorbital region is very noticeable. Clinical evaluation of orbital and periorbital symmetry should be undertaken with the patient in repose and in animation, i.e. varying gaze and raising/lowering the eyebrows.

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Midfacial Analysis

Chapter 13 The Ears

Introduction

The ear is not strictly speaking part of the face, but is part of the cranial region of the craniofacial complex. However, the ears lie on the same plane as the middle third of the face, and are an important parameter in facial aesthetic evaluation. As such, the clinical evaluation of the ears will be described in this section.

The external ear, or auricle, is usually a relatively inconspicuous feature of the craniofacial complex, which may be concealed under long hair in some individuals. However, excessively large, laterally prominent or deformed auricles may be very noticeable.

There is considerable individual variation in the size, shape and lateral prominence of the ears. Provided that the proportional relationship of the ears to the rest of the craniofacial complex is within normal limits, and there is relative left-right symmetry, these variations are deemed acceptable. Deformities may be a consequence of considerable deviation from normal morphology and size, and excessive disproportion of the ears. For children in particular, this may well become a source of ridicule by their peers, leading to personal anguish and emotional trauma.¹ For such patients, surgical alteration (otoplasty) may have a considerably favourable impact on their self-esteem.² The psychosocial experiences of children undergoing otoplasty have been examined, with 97% reporting an increase in happiness, 92% reporting an increase in self-confidence, 79% noting improved social experience with increased social integration, and 100% reporting bullying reduced or stopped; the report concluded that otoplasty is an effective procedure in alleviating psychosocial distress in the vast majority of children undergoing the operation.³

Terminology

- Anti- (prefix Greek: against, counter, opposite).
- Auditory (from Latin *audere*: to hear).
- Auricle (from Latin *auricular*: the external ear, diminutive of *auris*: an ear).
- Concha (Latin, from Greek *konche*: a shell).
- Crus (Latin: the leg between knee and ankle; plural: crura; refers to 'leg-like' parts or structures).
- Fossa (a shallow depression or hollow, from Latin: a ditch).
- Helix (Greek: a snail or a coil).
- Meatus (Latin: a passage).
- Otic (from Greek *otos*: ear).
- Pinna (Latin: wing).
- Scaphoid ('boat-shaped', from Greek *skaphos*: boat).
- Tragus (Latin, from Greek *tragos*: hairy projection of the ear; literally: a goat).

Anatomy

The ear houses the peripheral parts of the auditory and vestibular apparatus and is descriptively divided into the external, middle and internal ear. The anatomy of the **external ear** is important in facial aesthetic evaluation (Figure 13.1).

The external ear consists of the **auricle** (or **pinna**) and the **external acoustic meatus** (or **external auditory canal**). The auricle projects from the side of the head to collect sound waves,

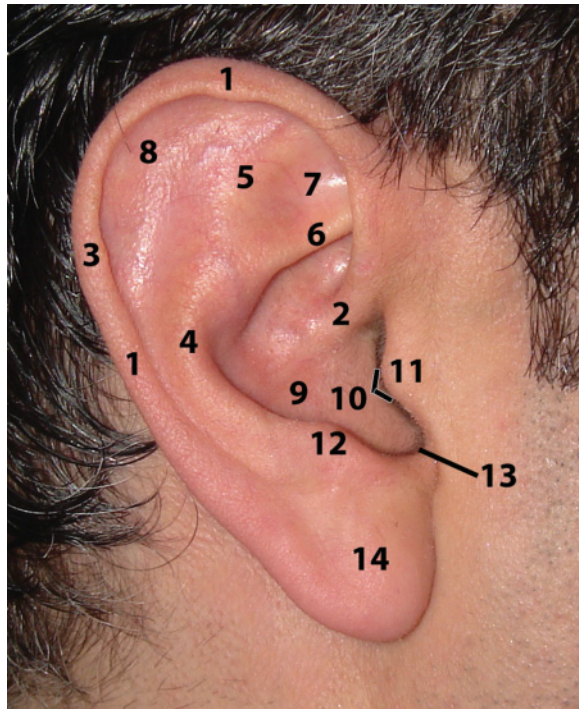


Figure 13.1 Anatomy of the external ear (auricle):

- 1 Helix
- 2 Crus of helix
- 3 Auricular tubercle
- 4 Antihelix
- 5 Superior crus of antihelix
- 6 Inferior crus of antihelix
- 7 Triangular fossa
- 8 Scaphoid fossa
- 9 Concha of auricle
- 10 External acoustic (auditory) meatus
- 11 Tragus
- 12 Antitragus
- 13 Intertragic notch
- 14 Lobule (ear lobe)

and the meatus leads inwards from the auricle to conduct vibrations to the tympanic membrane.

The framework of the auricle is the **auricular cartilage**; this is a single thin plate of resilient elastic fibrocartilage that is thrown into folds which give its characteristic shape. The cartilage is covered on both surfaces with adherent hairy skin, which continues into the external acoustic meatus. The cartilage of the auricle is prolonged inwards in tubular fashion as the cartilaginous part of the external auditory meatus, whose attachment to bone stabilizes the auricle in position.

The lateral surface of the auricle is irregularly concave, faces slightly forwards and displays numerous eminences and depressions; these convolutions may help to locate sound. Its prominent curved rim, or **helix**, usually bears a small **auricular tubercle** posterosuperiorly. The **antihelix** is a curved prominence, parallel and anterior to the posterior part of the helix. The



Figure 13.2 Attached ear lobe.

antihelix divides superiorly into **two crura** (superior and inferior crura of the antihelix), which flank a depressed **triangular fossa**. The curved depression between the helix and antihelix is the **scaphoid fossa**. The antihelix encircles the **concha** of the auricle, which is incompletely divided by the **crus** or anterior end of the helix. The **tragus** is a small curved flap below the crus of the helix and in front of the concha; it projects posteriorly, partly covering the meatal orifice. The **antitragus** is a small tubercle opposite the tragus and separated from it by the **intertragic notch**. Below this is the **lobule** (or **ear lobe**), which is a tag of skin containing fibrous and adipose tissue; the auricular cartilage does not extend into the ear lobe.

Note

The ear lobes may be *hanging* or *attached*. Hanging lobes are more common. Attached lobes are the result of recessive genes, i.e. both parents must have attached lobes if a child has attached lobes (Figure 13.2).

The soft ear lobe is commonly used for hanging jewellery, such as earrings. A far less common custom is ear lobe extension, involving hanging successively larger and heavier plugs into the ear lobes until they extend, sometimes dramatically.

Clinical evaluation

There is considerable **individual variation** in the size, shape, relative position and lateral protrusion of the ears. Nevertheless,

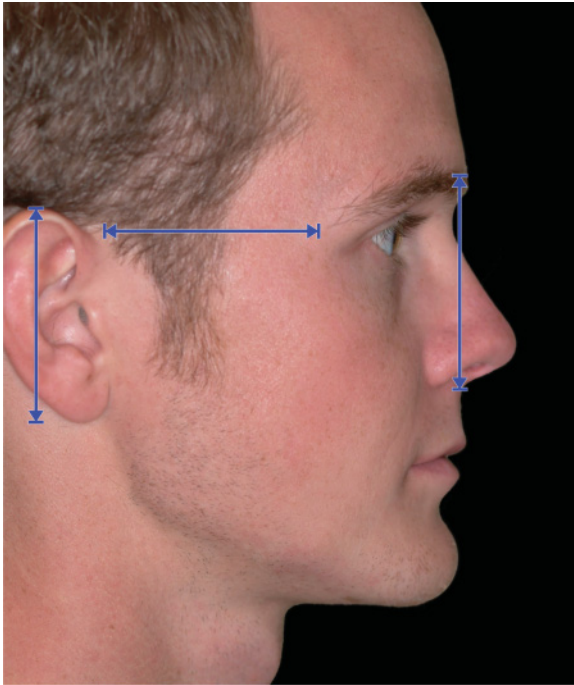


Figure 13.3 The ear is attached to the scalp approximately one ear height posterior to the lateral brow. Ear height is approximately equal to midfacial height.

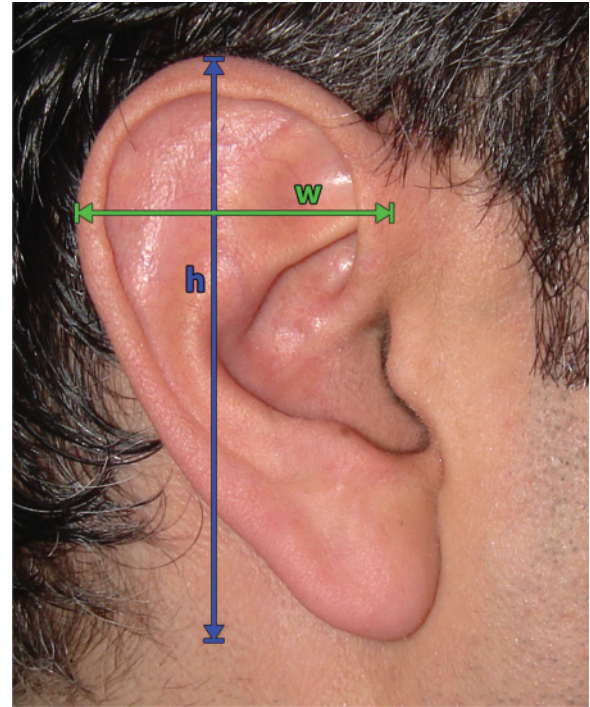


Figure 13.4 The width-to-height ratio of the ear is approximately 0.5 to 0.65:1; i.e. the width of the ear is about 60% of its height (normal range: 50–65%).

aesthetic guidelines for the external ear have been proposed, and are a useful starting point in clinical evaluation.

Ear position

- **Vertical position:** With the patient in natural head position (NHP), the top of the auricular helix should be at the level of soft tissue glabella and the brow, and the most inferior part of the ear lobe should be at the level of subnasale, i.e. the ear height should be approximately the same as midfacial height.⁴ This 'ideal' relationship is subject to considerable individual variability.
- **Sagittal position:** The ear is attached to the scalp approximately one ear height (65–75 mm) posterior to the lateral brow (or lateral orbital rim) (Figure 13.3).

Ear size and proportions

There is wide variation in ear size among individuals.

- **Ear height:** average 65 mm (range: 55–75 mm).
- **Ear width:** average 35 mm (range: 30–45 mm).
- **Width-to-height ratio:** The width-to-height ratio of the ear is approximately 0.5–0.65:1; i.e. the width of the ear is about 60% of its height (normal range: 50–65%) (Figure 13.4).
- **Vertical proportions:** The ear may be divided vertically into three approximately equal parts (Figure 13.5):
 - **Upper part:** From the top of the ear to the point of attachment of the helix to the side of the head; this

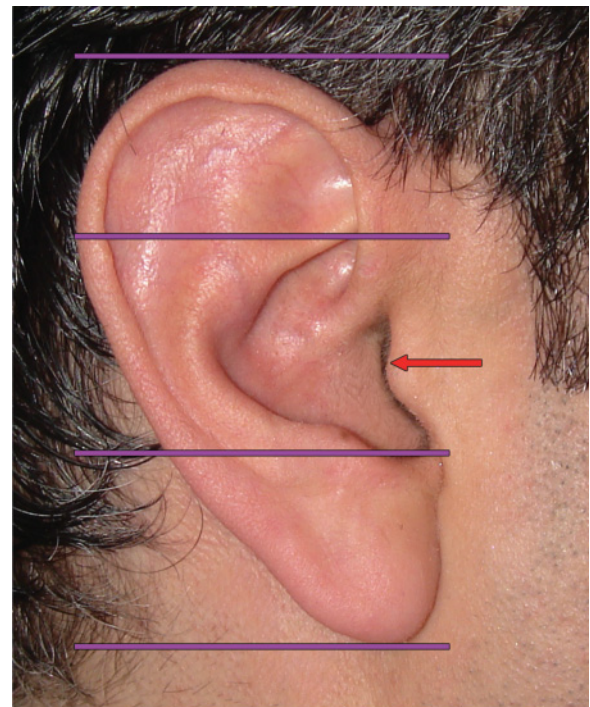


Figure 13.5 The ear may be divided vertically into three approximately equal parts with the tragus at the midpoint.

is approximately in line with the lateral canthus of the eye.

- **Middle part:** This region is occupied almost entirely by the concha. The tragus is at the midpoint of the ear.
- **Lower part:** The ear lobe.

Note

Timing of surgery: The average child will have completed 85% of auricular growth by the age of 3 years. Therefore, consideration may be given to setting back protruding ears as early as 3 years, but children seem to be more cooperative at 5–6 years, when the normal ear is almost fully developed.^{4,5}

Ear axis

The **ear axis**, or **long axis of the ear**, is defined as a line passing through the longest dimension of the ear.

- In profile view, the ear is posteriorly inclined, with its long axis inclined about 15–20° posteriorly from the true vertical plane (Figure 13.6).⁴
- In profile view, the line of the posterior aspect of the auricle and/or the long axis of the ear roughly parallels the dorsal plane of the nose.^{6,7}

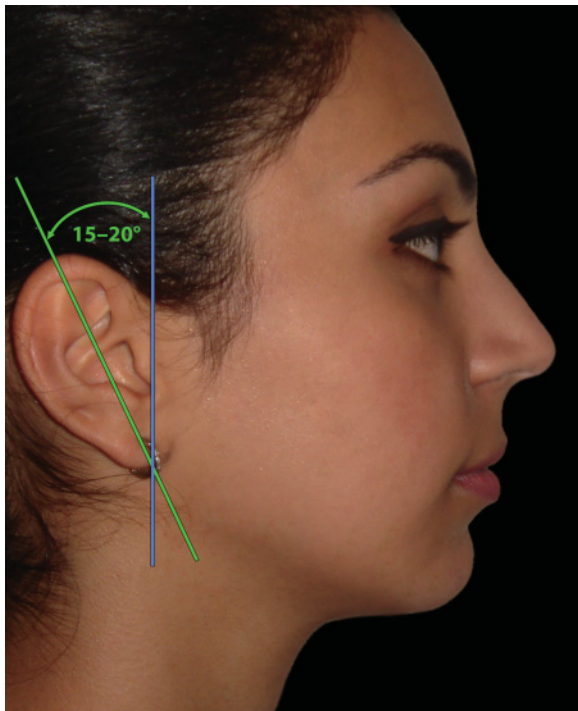


Figure 13.6 The long axis of the ear is inclined about 15–20° posteriorly from the true vertical plane.

- In posterior view, the outer helical rim stands away from the head at an angle of approximately 20° (Figure 13.7).⁴

Ear protrusion (lateral projection)

The term ‘prominent ears,’ refers to excessive lateral projection of the ears (Figure 13.8). The terms ‘bat ears’ or ‘lop ears’ should be avoided.

- **Auriculocephalic angle:** The ears should protrude from the posterior scalp covering the mastoid process about 25–35° (Figure 13.9).⁸
- **Distance:** The superior part of the helical rim should be about 10–15 mm from the scalp covering the squamous part of the temporal bone. The distance between the mastoid area and middle part of the posterior helical rim is between 15 mm and 20 mm (Figure 13.10).
- **Rule of fifths:** The lateral or outer fifth of the face is measured from the lateral canthus of the eye to the helix of the ear. Therefore, the outer helical rim of the ear should be close to the outer limit of the outer fifth of the face in frontal view (see Figure 9.25).

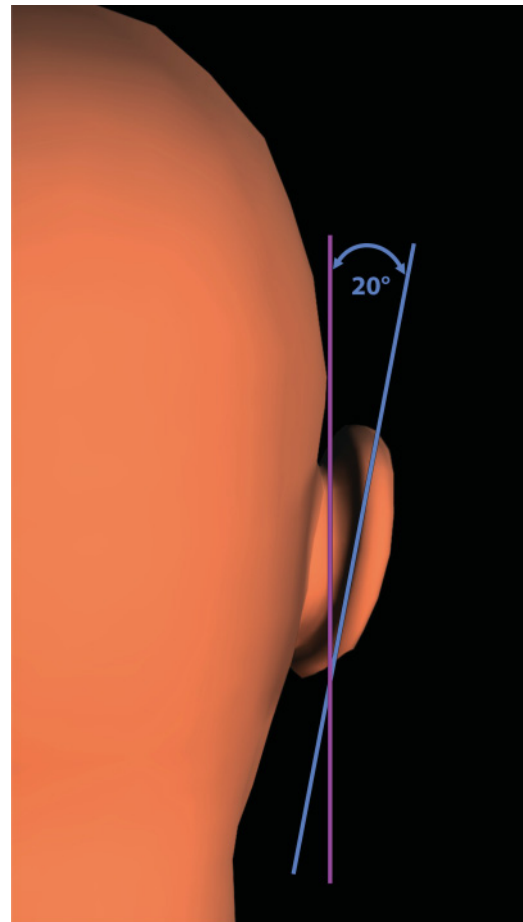


Figure 13.7 The outer helical rim stands away from the head at an angle of approximately 20°.



Figure 13.8 Excessive lateral projection of the ear.

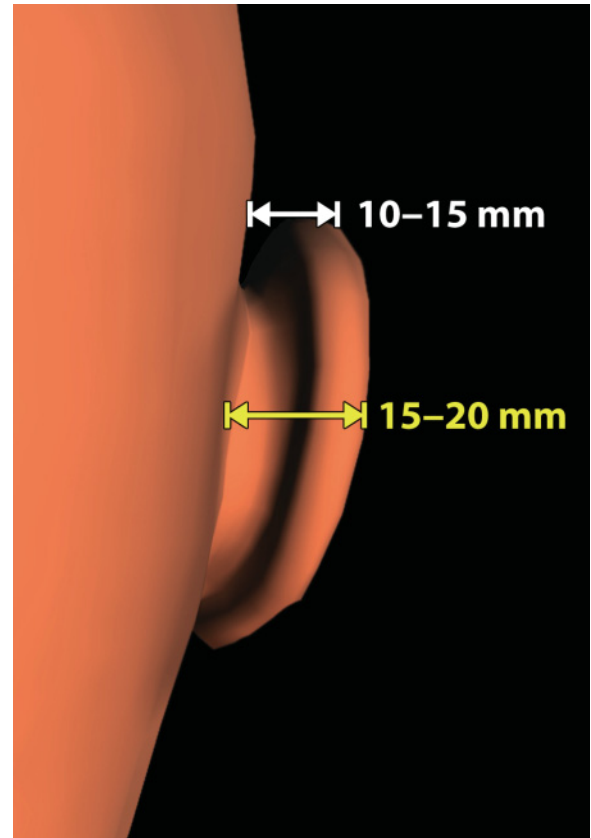


Figure 13.10 Ear protrusion (lateral projection): normal distances.

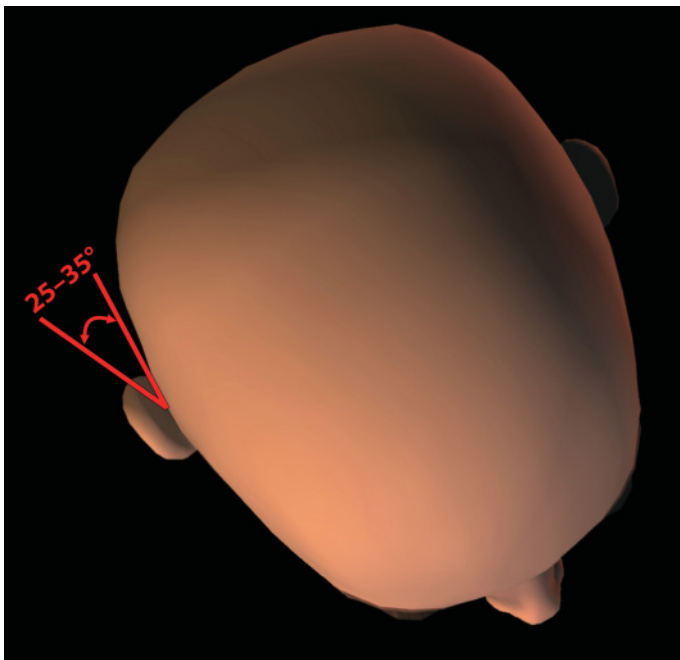


Figure 13.9 Auriculocephalic angle.

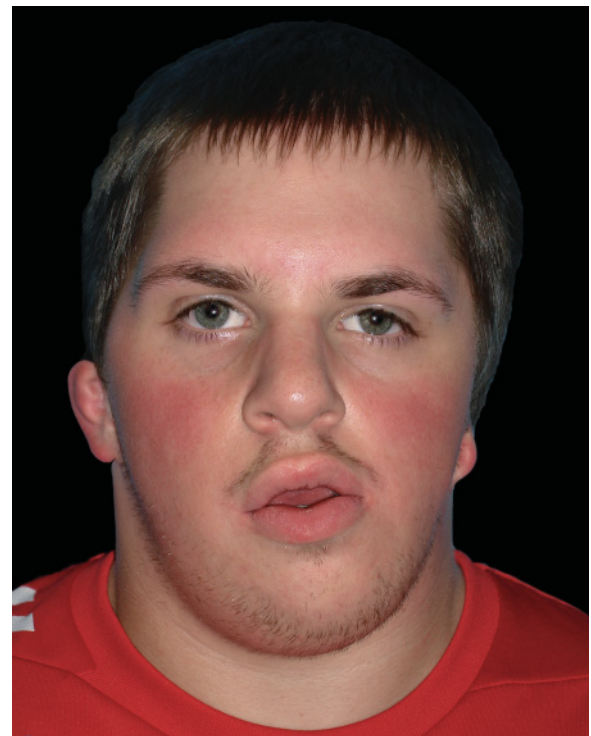


Figure 13.11 Asymmetrical ear morphology and position in patient with hemifacial microsomia.

Note

Principles in planning the correction of prominent ears
Posnick⁵ has described the basic objectives in the correction of prominent ears:

1. Correction of ear protrusion, with recognition of the varied degree of lateral projection in each region of the ear.
2. In *frontal view*, there should be visibility of both the helix and antihelix; the helix should form the most lateral extent of the auricle superiorly and should be just visible behind the antihelix and superior crus (avoidance of the 'telephone ear' deformity).
3. Achievement of a smooth antihelical fold.
4. Maintenance of a natural postauricular sulcus (excessive skin excision may flatten the sulcus) and thereby avoidance of a 'plastered-down' or 'operated' appearance.

Ear symmetry

It is important to evaluate the ears for bilateral symmetry. It is not uncommon for ear deformities to be asymmetrical (Figure 13.11).

The symmetry of the vertical position of the external auditory canals may be compared by placing a dental mirror handle in each meatus with the patient in NHP.

Note

This is particularly important when taking cephalometric radiographs, which must be taken with the patient in NHP. If clinical examination reveals that the patient's auditory canals are not level in the vertical plane with the patient in NHP, the cephalometric head positioning ear rods should not be used, to reduce the possibility of head rotation about the sagittal axis.

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Chapter 14 The Nose

Introduction

‘Cleopatra’s nose: had it been shorter, the whole face of the world would have changed.’

Blaise Pascal (1623–62),
Pensées (1670)¹

The nose occupies the central position of the face and is the most prominent part of the facial profile. The nose thereby has a dominating effect on the facial profile, helping to establish the character of the midface. It has profound emotional, social, cultural and functional significance.

The significance of nasal appearance has drawn the attention of writers throughout history. The most famous literary figure created by the playwright Edmond Rostand (1868–1918), Cyrano de Bergerac, was a character equally well known for his great skill in duels and his inordinately long nose. Cyrano loves Roxane, yet is afraid to reveal his emotions, fearing her rejection due to his large nose. Cyrano says: ‘I pride myself in such an appendage, considering that a large nose is the proper sign of a friendly, good, courteous, witty, liberal, courageous man, such as I am,’ yet a moment later he bemoans his nose as a curse.²

As a result of its importance in facial appearance, nasal aesthetic and reconstructive surgery has a long history. The first written record of nasal trauma surgery dates back as far as 2700BC to ancient Egypt and the physician **Imhotep**, as documented in the *Edwin Smith Papyrus*, a surgical treatise discovered in the nineteenth century by the American Egyptologist Edwin Smith (Figure 14.1).³ Smith recognized the importance of the document and bought it from a dealer in the city of Luxor

in 1862. The surviving papyrus was probably written around 1700 BC but may be a copy of originals written a thousand years earlier.

The earliest concepts of **reconstructive rhinoplasty** emerged in northern India in the sixth century BC, attributed to the surgeon **Susruta**.⁴ Susruta (pronounced ‘Sushruta’) was a surgeon and teacher of the (classic) **Ayurveda** (Sanskrit: the ‘science/knowledge of life’) tradition of the ancient Indian system of surgery. The surgical treatise *Susruta Samhita* (‘Susruta’s Collection’), compiled in Vedic Sanskrit, is attributed to him. At the time amputation of the nose was one of the prescribed punishments for an act of dishonour, such as adultery. Susruta described reconstruction of the resulting defect using a cheek flap. Susruta is also credited with having originated the classical **Indian method** of nasal reconstruction, using a forehead flap pedicled near the root of the nose, although the technique does not appear in the *Samhita*.

These works were lost for centuries, until Latin translations of the Persian physician **Ibn Sina’s (Avicenna) *The Canon of Medicine*** introduced the ideas into Europe. In 1441, the **Branca** family of Sicily became familiar with the techniques of Susruta, reintroducing the Indian cheek flap technique of nasal reconstruction in Italy. In 1597 the Italian surgeon **Gaspare Tagliacozzi** (1545–99) published a treatise entitled *De Curtorum Chirurgia per Insitionem*, which demonstrated the **Italian method** of nasal reconstruction using a pedicled flap from the arm (Figure 14.2).^{5,6}

After Tagliacozzi’s death, his work was deemed immoral and suppressed by the influential religious elite. Two centuries later a landmark article was published in England, as a ‘Letter to the Editor’ in the *Gentleman’s Magazine* (1794), describing Susruta’s

Figure 14.1 Plates 6 and 7 of the *Edwin Smith Surgical Papyrus*, shown here discussing facial and nasal trauma. (New York Academy of Medicine.)

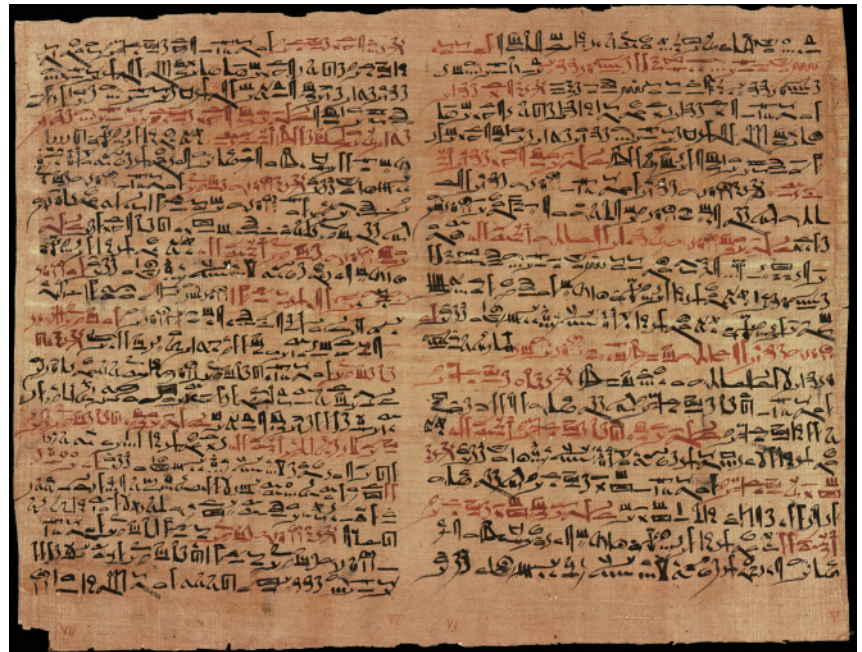


Figure 14.2 The Italian surgeon Gaspare Tagliacozzi (1545–99) published a treatise entitled *De Curtorum Chirurgia per Insitionem*, which demonstrated the 'Italian method' of nasal reconstruction using a pedicled flap from the arm.



'Indian method' of nasal reconstruction using a pedicled forehead flap (Figure 14.3). This article, appearing under the initials 'B.L.', marked the reintroduction of reconstructive rhinoplasty in Europe. The operation, performed by an unknown Indian brick-maker, on the defect from a previously amputated nose of a bullock driver named Cowasjee, had been witnessed by two British surgeons in India. The English surgeon **Joseph Constantine Carpie** (1764–1846) subsequently spent 20 years in India studying local plastic surgical methods, performing the first major reconstructive rhinoplasty in England (1815) dealing with the nasal reconstruction in two British officers (published in 1816).⁷ The term **rhinoplasty** was coined by the German

surgeon **Carl Ferdinand von Graefe** (1787–1840) as the title of his book (*Rhinoplastik*) published in 1818, describing both the 'Indian' and 'Italian' methods of nasal reconstruction.

The history of elective **aesthetic rhinoplasty** is inextricably linked to that of reconstructive nasal surgery, the development of general anaesthesia and the possibility of aseptic procedures. **Johann Friedrich Dieffenbach** (1792–1847) succeeded von Graefe in Berlin, and provided a description of the aesthetic rhinoplasty technique in his book (1845).⁸ Prior to 1887, rhinoplasty was a reconstructive procedure utilizing external incisions, and the first aesthetic rhinoplasty undertaken by an intranasal approach is attributed to the American otorhinolaryngologist

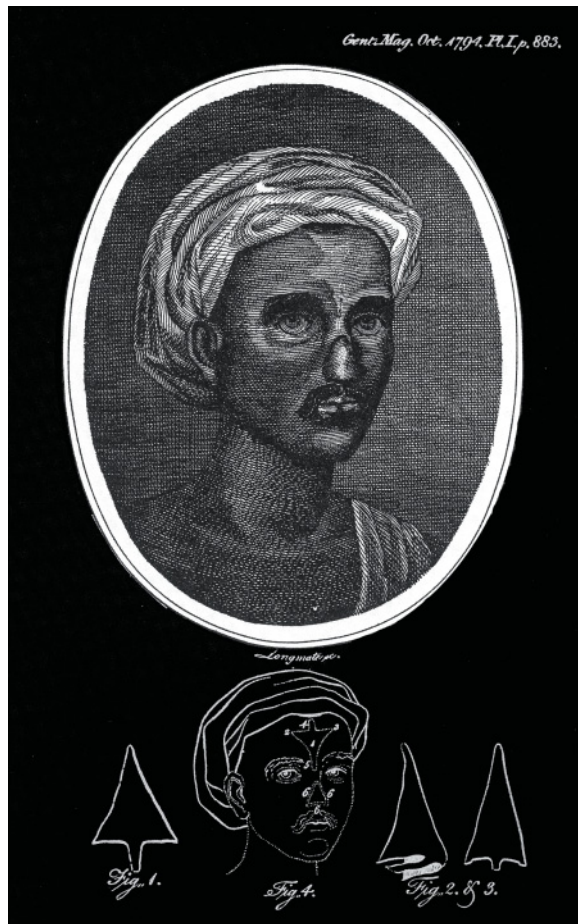


Figure 14.3 An article published in the *Gentleman's Magazine* (1794), describing Susruta's 'Indian method' of nasal reconstruction using a pedicled forehead flap marked the reintroduction of reconstructive rhinoplasty into Europe. The first publication of this illustration appeared a year earlier in the *Madras Gazette* (1793).

John Orlando Roe (1848–1915) from Rochester, New York. However, the father of modern aesthetic rhinoplasty is acknowledged to be the Prussian-born German **Jakob Lewin (Jacques) Joseph** (1865–1934), who originally trained as an orthopaedic surgeon in Berlin (Figure 14.4). Joseph preferred the external approach to rhinoplasty, stressing the importance of direct visualization of the component parts. The publication of Joseph's book (1931) is considered a landmark in aesthetic surgery.⁹ Two of Joseph's pupils, the Polish American **Joseph Safian** (1886–1983) and **Gustave Aufricht** helped publicize Joseph's methods; Safian brought Joseph's methods to New York and Aufricht later travelled to America gaining a reputation as a respected aesthetic surgeon.¹⁰

Refinements in the rhinoplasty technique owe much to the modern pioneers of aesthetic rhinoplasty, such as **Thomas D Rees**, **Jack H Sheen** and **M Eugene Tardy Jr**, particularly the emphasis on maintaining and/or improving nasal function while *conservatively* creating results that appear 'natural' rather than 'operated'.



Figure 14.4 Jacques Joseph (1865–1934), considered to be the father of modern aesthetic rhinoplasty.

Note

In addition to modification of form and improvement in nasorespiratory function, attention to the *psychosocial* status of the patient is paramount. Jacques Joseph maintained that the driving force for aesthetic rhinoplasty was not vanity; it was *not* the desire to be more beautiful than the average human being. The *motivation* was the desire to be free from disfigurement and to be inconspicuous. The word Joseph used to describe such motivation was **antidysplasia**, i.e. the feeling of being disfigured and the aversion to such disfigurement and its emotional and material consequences.

'Rhinoplasty seeks to cure psychological depression by restoring a normal shape to the nose. Its social importance is beyond question, and it represents a significant branch of surgical psychotherapy.'

Jacques Joseph (1865–1934)¹¹

Terminology

- Ala (Latin: a wing; plural: 'alae').
- Apex (Latin: tip).
- Caudal (from Latin *cauda*: a tail).
- Cephalic (from Greek *kephale*: head).
- Crus (Latin: the leg between the knee and ankle; plural for two: 'crura'; more than two: 'crurae'), i.e. it is the anatomical nomenclature for a 'leg-like' part.
- Dorsum (Latin: the back).
- Nares (Latin, plural of naris: a nostril).
- Naso-, nas- (from Latin: nose).
- -plasty: (from Greek *plastikos*: moulded, formed).

- Radix (Latin: root).
- Rhino- (from Greek *rhis*, *rhin*:-: nose).
- Septum (Latin: a fence, i.e. a partition).

Note

The 'nasal dorsum'/'dorsal surface' of the nose are accepted terms, but actually refer to the *ventral* aspect of the nose.

Anatomy

The nose consists of the **external nose** and the **nasal cavity**, which is divided into right and left halves by the midline **nasal septum**. The supporting framework of the external nose is *bony* in the upper third and *cartilaginous* in the middle and lower thirds.

Soft tissue features of the external nose

The external nose is 'pyramidal' in shape (Figure 14.5).⁹ Its cephalic most part, or **root (radix nasi)**, is continuous with the forehead, and its free **tip** forms the **apex**. Inferiorly are the **external nares (nostrils)**, two ellipsoidal apertures separated by the nasal septum and columella. The external nares are narrower anteriorly, measuring approximately 15–20 mm sagittally and 5–10 mm transversely. The lateral surfaces of the external nose unite in the median plane to form the 'bridge' of the nose or **nasal dorsum (dorsum nasi)**, the shape of which exhibits great individual variability. The upper part of the external nose is kept

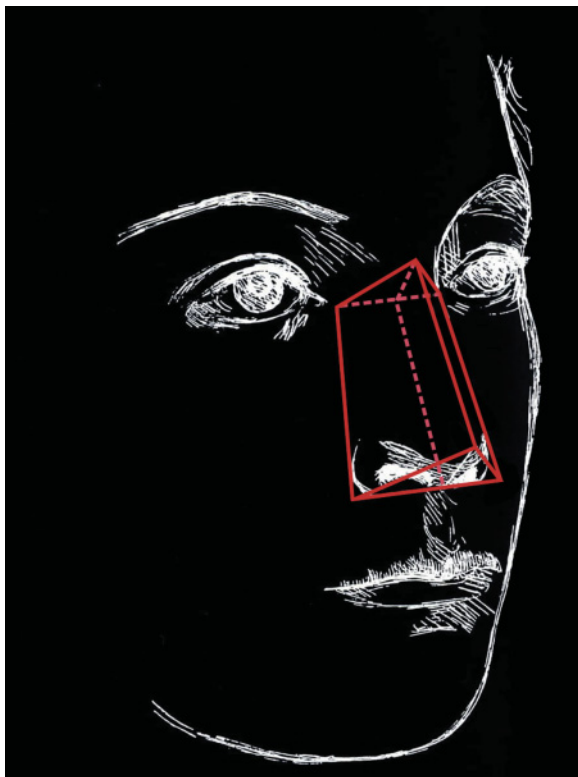


Figure 14.5 The external nose is *pyramidal* in shape. (Redrawn from Joseph.)⁹

patent by the nasal bones and the frontal processes of the maxillae. Below this the nasal cartilages form the walls of the external nose, supported in the midline by the cartilaginous part of the nasal septum. The lateral surfaces end below in the rounded **alae nasi**.

Skin of the external nose

The external nose is covered by skin that plays an important role in the final appearance of the nose after rhinoplasty. The skin is closely adherent to the underlying alar cartilages, but loosely attached and relatively mobile over the lateral (upper) cartilages and nasal bones. The skin is thicker over the tip (apex) and alae. The adherent skin over the nasal tip contains many sebaceous glands, which tend to progressively diminish in number superiorly. The skin extends into the **vestibule** immediately within the nostrils, where it has a variable crop of stiff hairs; the mucocutaneous junction lies behind the hair-bearing area.

Note

Nasal skin thickness is a critical factor in preoperative analysis; the nose should be palpated to assess the skin thickness. In patients presenting with extensive subcutaneous fat and abundant sebaceous glands, the skin may not adapt well to surgical alteration of the osseocartilaginous framework. Conversely, very thin skin may be very unforgiving, highlighting the most minor irregularities or contour defects of the underlying framework.

Bony skeleton of the external nose

The osseous framework supporting the upper third of the external nose consists of the nasal bones, the frontal processes of the maxillae and the nasal processes of the frontal bones (Figure 14.6).



Figure 14.6 The osseous framework supporting the upper third of the external nose.

- 1 Nasal bone
- 2 Frontal process of maxilla
- 3 Nasal process of frontal bone

Cartilaginous skeleton of the external nose

The cartilaginous framework of the external nose consists of the:

- **Septal cartilage** (Figure 14.7): This median cartilage is almost quadrilateral in shape in lateral view, hence the alternative term **quadrangular cartilage**.
- **Upper lateral (nasal) cartilage (paired)** (Figures 14.8 and 14.9): The upper lateral nasal cartilage is triangular, its anterior margin being thicker than the posterior. The upper part is continuous with the septal cartilage, but anteroinferiorly it may be separated from it by a narrow fissure. The cephalic margin of the upper lateral nasal cartilage is attached to the nasal bone and frontal process of the maxilla. The cephalic aspect of the upper lateral cartilage extends beneath the caudal aspect of the nasal bones for a variable distance; this bony-cartilaginous overlap is approximately 9 mm in the midline but reduces to 4 mm laterally.¹² The caudal margin of the upper lateral cartilage is connected by fibrous tissue to the lateral crus of the major alar cartilage.
- **Major alar cartilage (paired)** (Figures 14.8 and 14.9): The major (or greater) alar cartilage is a thin flexible plate lying below the lateral nasal cartilage. It is curved acutely around the anterior part of its naris, forming two 'legs', the medial

(relatively vertically directed) crus and lateral (relatively horizontally directed) crus. The narrow **medial crus** (septal process) is loosely connected by fibrous tissue to its contralateral fellow and to the anteroinferior part of the septal cartilage. The **lateral crus** lies lateral to the naris and runs superolaterally away from the margin of the nasal ala. The upper border of the lateral crus is attached by fibrous tissue to the lower border of the upper lateral nasal cartilage. Its lateral border is connected to the frontal process of the maxilla by a tough fibrous membrane containing three to four **minor alar nasal cartilages**, alternatively termed the **sesamoid** or **accessory** cartilages. The lateral crus of the major alar cartilage is shorter than the lateral margin of the naris; the lateral part of the margin of the ala is fibroadipose connective tissue covered by skin.

The acute angulation formed anteriorly at the **transitional junction** between the medial and lateral crura creates a projection termed a **dome**; this is the highest point on the nasal tip. The two domes are separated by a notch palpable at the tip of the nose.



Figure 14.7 The osseocartilaginous nasal septum (paramedian sagittal section). The septal cartilage is almost quadrilateral in shape in lateral view, hence the alternative term quadrangular cartilage.

- 1 Nasal bone
- 2 Perpendicular plate of ethmoid bone
- 3 Vomer
- 4 Anterior nasal spine (maxilla)
- 5 Septal cartilage
- 6 Cut edge of lateral nasal cartilage

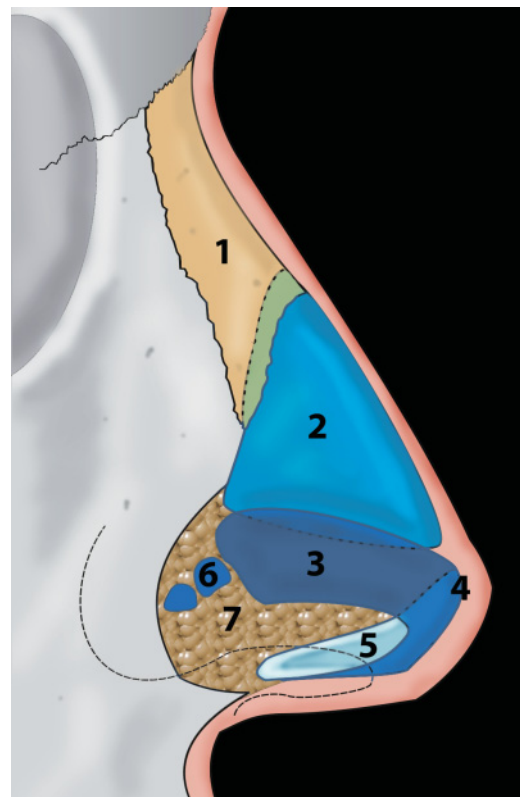


Figure 14.8 The bones and cartilages of the external nose (lateral view).

- 1 Nasal bone
- 2 Upper lateral cartilage
- 3 Lateral crus of major alar cartilage
- 4 Dome
- 5 Medial crus of major alar cartilage
- 6 Minor (accessory) cartilages
- 7 Fibroadipose connective tissue

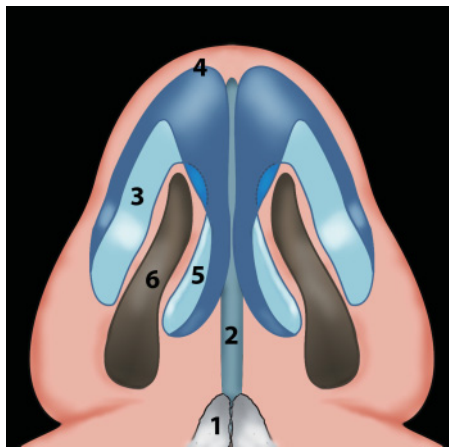


Figure 14.9 The bones and cartilages of the external nose (caudal view).

- 1 Anterior nasal spine
- 2 Septal cartilage
- 3 Lateral crus of major alar cartilage
- 4 Dome
- 5 Medial crus of major alar cartilage
- 6 Nostril

The strut formed by the medial crura of the alar cartilages and the overlying skin that lies between the tip of the nose and subnasale is termed the **columella**. The columella is connected to the nasal septum posteriorly by the **membranous septum**, which is the caudal part of the nasal septum between the nares that is devoid of cartilage.

Note

Sheen¹³ stated that as a *functional* organ, the nose may be divided into three compartments (from cephalic to caudal):

- **The bony vault:** formed by the paired nasal bones and the frontal processes of the maxillae.
- **The upper cartilaginous vault:** formed by the upper lateral cartilages.
- **The lower cartilaginous vault:** formed by the major alar cartilages.

These have in common a supporting partition, the bony and cartilaginous nasal septum, which essentially creates two separate and complete functioning halves in each nose.

Nasal type, topography and the subunit principle

Classification of nasal type

The nose is arguably the most variable aesthetic unit of the face. Leonardo da Vinci described a variety of nasal types in profile view, writing (Figure 14.10):^{14,15}

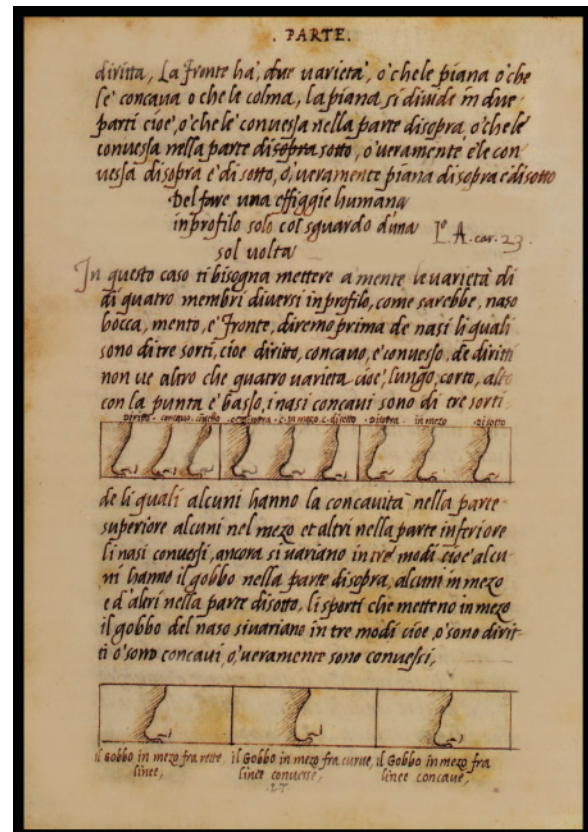


Figure 14.10 Variations in nasal type in profile view. (Leonardo da Vinci, c. 1530–50; Biblioteca, Vatican City.)

‘Let us speak first of noses, of which there are three types, that is, straight, convex and concave. Of the straight type there are only four varieties, that is, long, short, high at the tip and low at the tip. Concave noses are of three types, of which some have the concavity on the upper portion, some in the middle, and others on the lower part. Convex noses again vary in three ways, that is, some have the projection on the upper portion, some in the middle and others in the lower part. The contours on either side of the projecting part of the nose vary in three ways, that is, they are straight, concave or extremely convex.’

Nasal index (Figure 14.11)

The **nasal index** reflects the width-to-height ratio of the nose (ratio of alar width to nasal height). It may be calculated by the formula:

$$\text{Nasal index} = \frac{\text{Nasal interalar width (Al-Al)} \times 100}{\text{Nose height (N'-Sn)}}$$

Farkas¹⁶ has provided values for North American Caucasians:

- Average nasal index: 65 ± 5 .
- Male: 66 ± 7 .
- Female: 64 ± 5 .

A broad nose (nose wide for its height) has a high index value; a narrow nose (nose narrow for its height) has a low index value.

Ethnic variation (Figure 14.12)

In general, nasal morphology correlates relatively well with ethnic background, though considerable *individual variability* remains. Diagnosing clinicians should respect such ethnic nasal variation, striving to improve and refine the nasal appearance while maintaining ethnic features. There are three broad categories of nasal appearance commensurate with ethnic background (Table 14.1).¹⁷

- **Leptorrhine:** The 'tall and narrow' or **Caucasian** nose is usually found in northern European and Mediterranean ethnic groups (Greek *leptos*: thin and narrow). The excessively tall, thin nose is termed **hyperleptorrhine**.

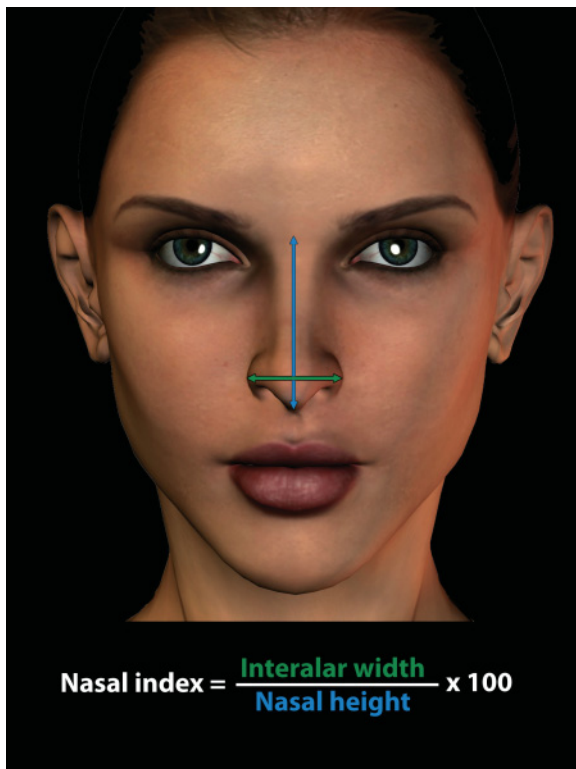


Figure 14.11 Nasal index.

- **Mesorrhine:** The 'intermediate' ('medium') or **Far Eastern** nose is characterized by reduced dorsal projection and wide dorsum, reduced tip projection and short columella (Greek *mesos*: medium/average).
- **Platyrrhine:** The 'broad and flat' or **black** nose is characterized by reduced radix projection, reduced dorsal length, concave dorsum, reduced nasal tip projection, flared alae with wide nostrils and thick skin (Greek *platys*: wide/broad). An alternative term for platyrrhine is **chamaerrhine**. The excessively broad and flat nose is termed **hyperplatyrrhine** (or **hyperchamaerrhine**).

Note

The clinician must be sensitive to clues from the patient, particularly in the interview stage of the consultation, if they are suggestive of **ethnic dysphoria**, i.e. the patient evaluates his or her nasal appearance unfavourably (body image issues related to **ethnic identity**), often with considerably negative emotional experience, and wants alterations akin to another ethnic background. In the same context is **gender dysphoria**, e.g. a male patient requesting a nasal type that is obviously feminine (body image issues related to **gender identity**). In such situations the clinician is advised not to operate, and to inform the patient in a polite and straightforward manner, stressing the fact that they are acting in the best interests of the patient; subsequent referral to a clinical psychologist or psychiatrist may be required.

Topographic nasal landmarks and nomenclature

Relative nasal spatial relationships (Figure 14.13)

Descriptive terminology regarding the spatial relationships of the nose *relative* to the rest of the craniofacial complex is important, permitting clear description of nasal morphology for diagnosis and treatment planning. The main axis of the nose is at an angle to that of the face.¹⁸ **Craniofacial spatial relationships** are described as superior, inferior, anterior and posterior. **Nasal spatial relationships** may be described as 'cephalic'/'cranial', 'caudal', 'dorsal' and 'basal'.

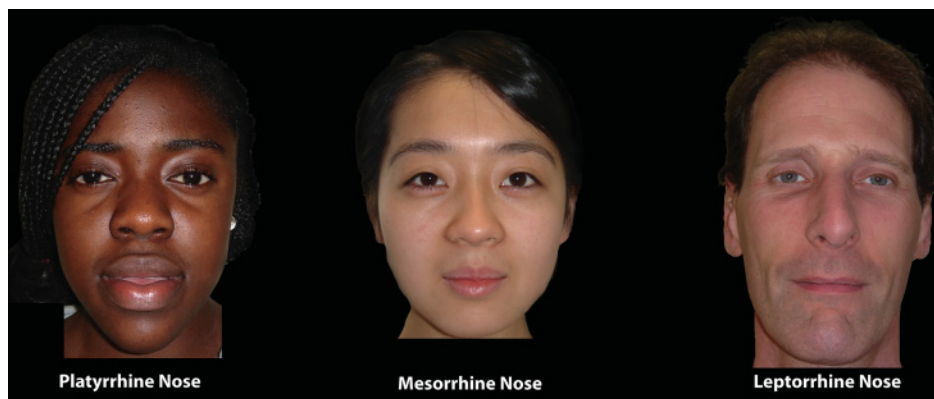


Figure 14.12 Ethnic variations in nasal type.

Table 14.1 Classification of nasal type according to nasal index

Nasal type	Nasal index
Hyperleptorrhine (excessively tall and narrow)	≤54.9
Leptorrhine (tall and narrow)	55.0–69.9
Mesorrhine (medium)	70.0–84.9
Platyrrhine (broad and flat)	85.0–99.9
Hyperplatyrrhine (excessively broad and flat)	≥100.0

Values according to Lang et al.¹⁷

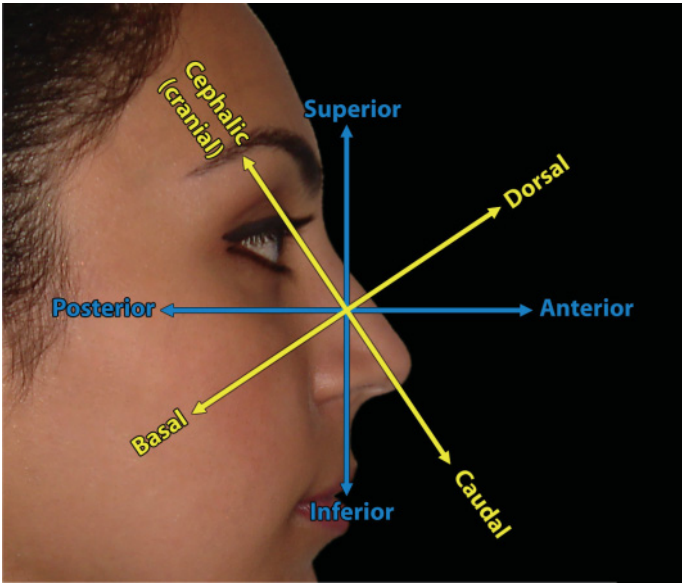


Figure 14.13 Descriptive terms for relative nasal spatial relationships. (After Austermann.¹⁸)

The framework of the **nasal dorsum** (‘dorsum nasi’ or ‘nasal bridge’) consists of the **bony dorsum** and **cartilaginous dorsum**. The **rhinion** (osseocartilaginous junction) is located at the junction of the nasal bones and upper lateral nasal cartilages (Figure 14.14); this region is termed the **keystone area** because of its key importance in stabilizing the nasal dorsum.

Nasal height (Figure 14.15)

Nasal height is the vertical distance from nasion (N') to subnasale (Sn).

Nasal length

Nasal length is the vertical distance from nasion (N') to the nasal tip (pronasale, Prn).

Note
It is important not to confuse the terms ‘nasal height’ and ‘nasal length’.

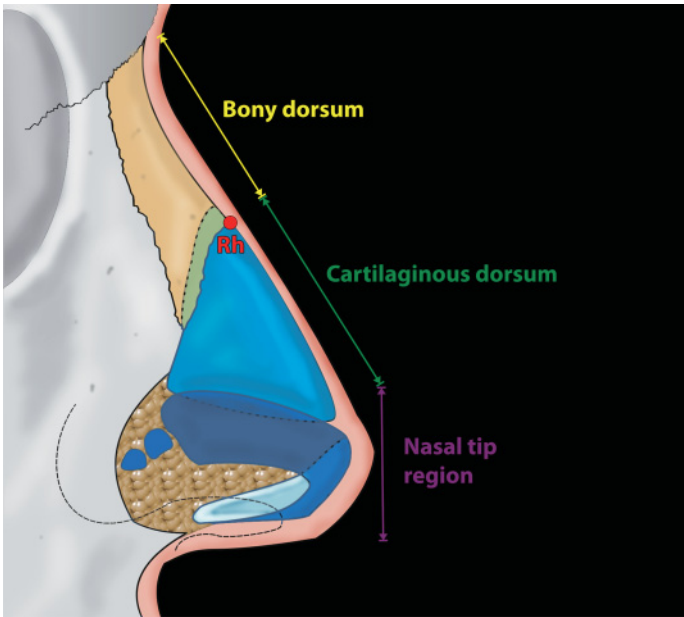


Figure 14.14 The nasal framework. The rhinion (Rh) marks the osseocartilaginous nasal junction.

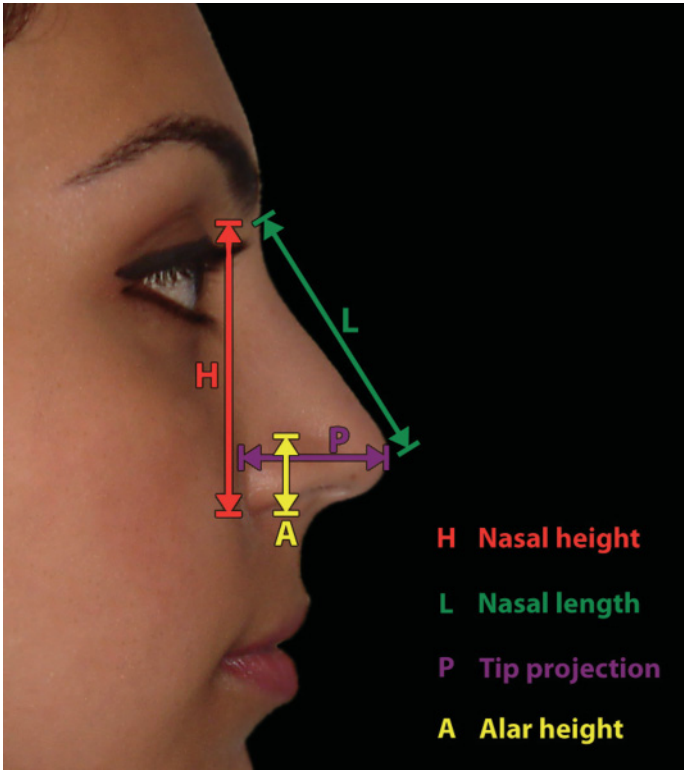


Figure 14.15 Nasal height, length and projection.

Nasal tip projection

This is the horizontal distance from the alar-facial crease to the nasal tip. The projection of the nose from the face may also be measured from subnasale (sometimes termed ‘nasal depth’).

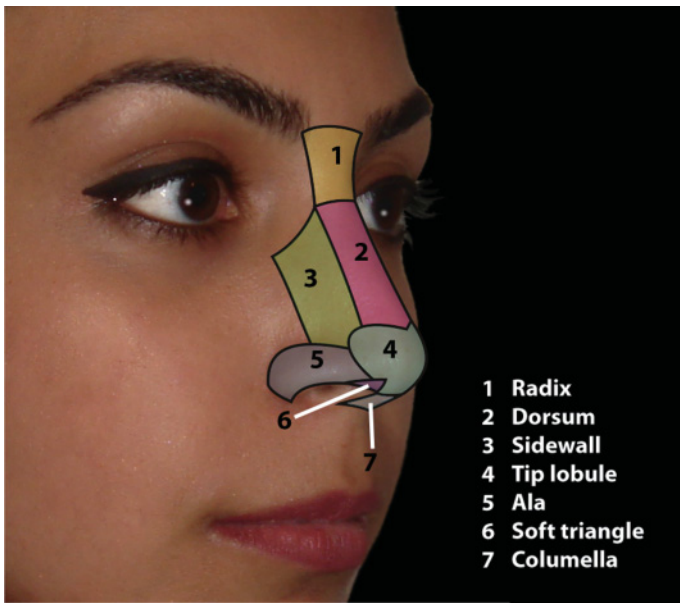


Figure 14.16 Nasal aesthetic subunits.

Nasal aesthetic subunits

The external nose represents a **facial aesthetic unit** located in the centre of the face, comprising a number of aesthetic **subunits** (Figure 14.16):¹²

- **Nasal radix:** The root of the nose.
- **Nasal dorsum:** The dorsum extends from the caudal end of the radix to the supratip breakpoint, where the nasal lobule commences, i.e. the dorsum connects the nasal root to the nasal tip.
- **Nasal sidewalls:** The lateral wall of the nose, connecting the nasal dorsum to the face.
- **Nasal lobule:** The lobule of the nose includes the tip (apex), columella and alae. As an anatomical subunit, it also includes the membranous septum and the internal structures surrounded by the lobule. The lobule is the mobile portion of the nose as there is no fixed cartilaginous or bony continuity. The septum and lateral nasal cartilages are connected only by connective tissue.¹⁹

The lobule itself may be considered as a number of adjoining subunits:

- **Tip (anterior) lobule:** This is the area dorsal to the nostrils (in profile view), between the columellar breakpoint and the supratip breakpoint. It includes the **domal region** and **infratip lobule**.²⁰
- **Columella:** The column of skin that separates the nostrils at the base of nose. Millard²¹ described the columella as 'the centre prop that supports the nasal tip'.
- **Soft triangles (nasal facets):** This refers to the thin fold of skin at the anterior junction between the alar rim and nasal tip, spanning the area between the medial and lateral crura. This area is devoid of cartilage.

- **Alar lobules (alar sidewalls):** The inferolateral eminence forming the lateral wall of each nostril.

Note

The borders of the nasal aesthetic subunits define natural demarcations and facial 'shadows', which permit the placement of incisions such that the resultant scars are less obvious to the naked eye.

Clinical evaluation

Systematic and thorough clinical *inspection* and *palpation* is the cornerstone of aesthetic nasal evaluation. It is important to analyse the nose as an independent facial unit, and also to evaluate its size, morphology and position *relative* to its neighbouring facial structures and the entire craniofacial complex. The patient is examined in natural head position with the teeth lightly in occlusion and the facial soft tissues in repose.

Note

It is important to emphasize that the general aesthetic guidelines must be employed with an understanding of individual, sex and ethnic variations.

Frontal evaluation

Vertical proportions

Midface height (glabella to subnasale) should be approximately equal to lower anterior face height. Nasal height (nasion to subnasale) is approximately 45% of lower anterior face height.

Transverse proportions

- The **alar base width** should be approximately equal to the intercanthal width, which is equal to one eye width. This guideline is based on the 'rule of fifths', where the face is divided by vertical lines into equal fifths, each approximately the width of one eye. Guyuron²² has suggested that alar base width may be 1–2 mm wider than intercanthal width.

Note Anterior and/or superior repositioning of the maxilla tends to increase the alar base width. This may be partially counteracted by the placement of an alar 'cinch suture' at the time of surgery to maintain the alar base width. The width of the alae may be narrowed several millimetres by careful **alar wedge resection**.

- **Radix width** (nasal root width) should be approximately one-third of the intercanthal distance.
- The **upper nasal width** is approximately 70–80% of alar base width.
- **Nasal width-to-length ratio:** The alar base width should be approximately 70% of nasal length (nasion to pronasale).²³

Nasal symmetry and asymmetry

Mild nasal asymmetry is very common, but may often not be noticed by patients preoperatively. Patients tend to scrutinize

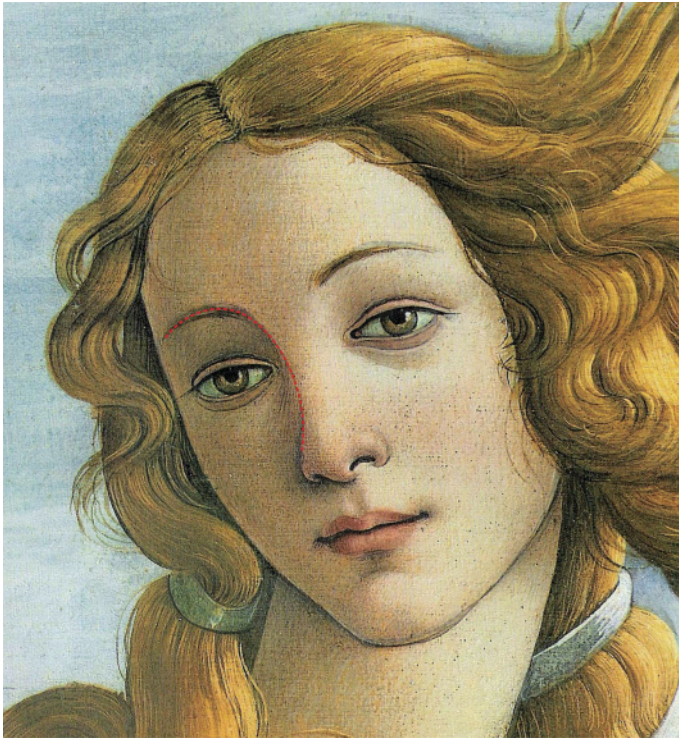


Figure 14.17 Brow-nasal tip aesthetic line. (Detail, *Birth of Venus*, c. 1485, Sandro Botticelli, Galleria degli Uffizi, Florence.)

their facial appearance far more following surgery; pre-existing nasal asymmetries, if not fully discussed with the patient preoperatively or not fully corrected with surgery, may become anathema to the patient following surgery.

- **Nasal midline:** Glabella, nasion, the midline of the nasal dorsum, pronasale, columella and subnasale should all fall on a straight line, coincident with the facial midline.
- **Brow-nasal tip aesthetic line** (Figure 14.17): This aesthetic line, from the medial eyebrow to the nasal tip, should be smooth, gently curving and devoid of contour defects bilaterally.
- **Tip defining points and 'dome' symmetry:** The nasal tip or domal region has two tip defining points, termed the **domal defining points**, which represent light reflection from the skin overlying the domes created by the anterior projection of the transitional junction between the medial and lateral crurae. Asymmetry observed in the domes may result in nasal tip asymmetry in frontal view. Excessive distance between the domal tip defining points, sometimes termed **tip bifidity**, may result from exaggerated *divergence of the domes*, which may need to be drawn together during surgery (Figure 14.18). The normal angle of divergence has been described as between 35° and 60°. ^{18,24}
- **Alar symmetry:** Any asymmetry between the right and left alae must be noted, including height, width, shape and position of attachment to the alar base.

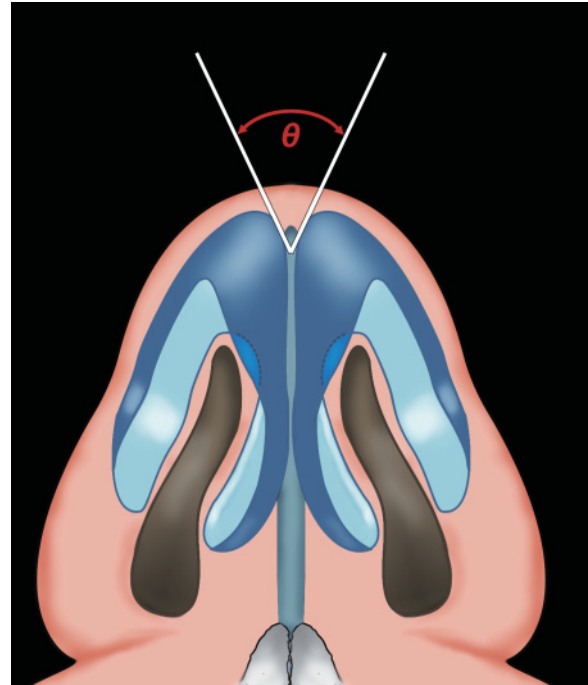


Figure 14.18 The normal angle of divergence of the domes has been described as between 35° and 60°. Excessive distance between the domal tip defining points may result in tip bifidity.

Nasal tip morphology

Sheen¹³ described the nasal tip as the nasal surface area contained within four tip defining points: the left and right domal defining points, supratip breakpoint and columellar breakpoint. Connection of these four landmarks should create two equilateral triangles (Figure 14.19).

The distance between the domal tip defining points is an important factor in nasal tip aesthetics, and relates to the divergence of the transitional segment that joins the medial and lateral crura.

Columella–alar relationship (frontal view)

The columella is observed to hang just inferior to the inferior alar rims, giving the infratip lobule and alae a gentle 'gull in flight' appearance on frontal view, the columella being the gull's body and the alar rims being the wings (Figure 14.20).

- **Hanging columella:** Excessive exposure of the columella on frontal view indicates inferior protrusion of the columella.
- **Retracted columella:** Lack of columella exposure on frontal view, which may require augmentation.

Note

The base of the columella should have a caudal projection in relation to the base of each ala in frontal view, forming the **columella-ala triangle** (Figure 14.21).²⁵

Profile evaluation

Radix evaluation

Daniel²⁶ has described the importance of the radix area ('root' of the nose or 'radix nasi') in nasal aesthetic evaluation. In aesthetic evaluation, it is critical to distinguish between the radix area and the nasion:

- **Radix:** This refers to the *area* centred at the nasion, extending inferiorly to the level of the lateral canthus and superiorly for a comparable distance.²⁷
- **Nasion (N):** This refers to a specific anatomical point or soft tissue landmark in the midline of the nasal radix. Skeletal nasion (N) is the midpoint of the nasofrontal suture. The vertical level of the soft tissue nasion (N') and skeletal nasion is identical; the slight groove of the nasofrontal suture may be felt by the clinician gently palpating the region with his or her fingernail.

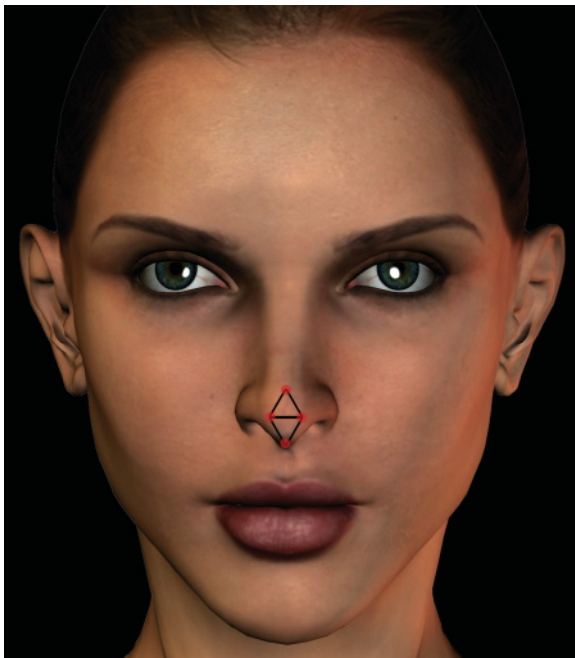


Figure 14.19 Sheen¹³ described the nasal tip as the nasal surface area contained within four tip defining points: the left and right domal defining points, supratip breakpoint and columellar breakpoint. Connection of these four landmarks should create two equilateral triangles.

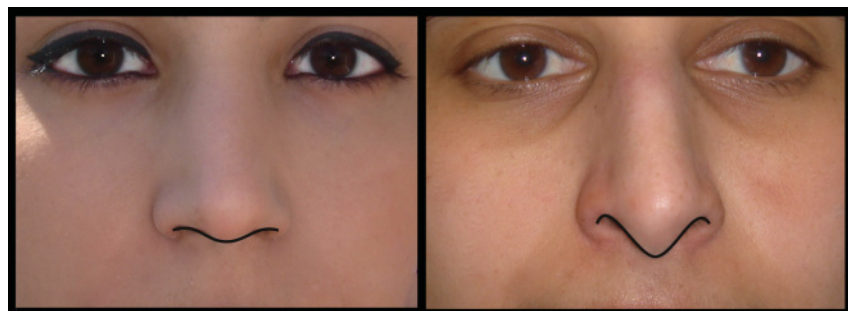


Figure 14.20 Left panel: The columella is observed to hang just inferior to the inferior alar rims, giving the infratip lobule and alae a gentle 'gull in flight' appearance on frontal view. Right panel: Excessive exposure of the columella on frontal view may indicate inferior protrusion of the columella.

These two parameters are linked by the **nasofrontal angle**, which is described below. The nasofrontal angle is an important aesthetic determinant on profile view; however, the vertical level and sagittal projection of the nasion are equally important.

Nasion position

Nasion is an important landmark that is used in a number of nasal and facial aesthetic analyses; determination of the *location* of soft tissue nasion in the vertical and sagittal planes in the preoperative evaluation is paramount.

- **Vertical position** (Figure 14.22A): The nasion level or vertical position is usually set between the **superior palpebral fold** and the **eyelashes** of the upper eyelid, 'ideally' about 2 mm above the lash line and 5 mm above the intercanthal line.²⁸ Guyuron²² prefers the nasion level to be placed at the lower border of the upper lid margin on straight gaze. Sheen²⁹ suggests that a lower level of the nasion, such as at the **mid-pupil**, may be acceptable, as it provides 'softening' of the profile, which may be desired in certain cases. The various specifications, *ranging from midpupil to superior palpebral fold*, permit the nasion level to vary over a 12-mm range.

Note

The higher the vertical level of nasion (i.e. towards superior palpebral fold), the 'stronger' the nose; the nose will also appear longer. Conversely, the lower the vertical level of nasion (i.e. towards the midpupil), the 'softer' the nose; the nose will also appear shorter.²⁹

- **Sagittal projection** (Figure 14.22B): The nasion projection (sometimes termed nasion 'height') may be determined in relation to vertical lines tangent to the anterior cornea or glabella, or from the medial canthus.
 - **From glabellar plane:** The *depth* of the nasion is normally 4–6 mm posterior to glabella, sometimes termed the **nasofrontal depression**; Guyuron based the above values on observations of 1619 life-size facial profile photographs.²²
 - **From anterior corneal plane:** Byrd and Hobar³⁰ advised determining the ideal nasal length (nasion to nasal tip) and multiplying by 0.28 to calculate 'ideal' nasion projection from the anterior corneal plane. Direct measurements from patient profiles demonstrated a normal range of between 9 mm and 14 mm anterior to the corneal plane.

- **From medial canthus:** Goldman³¹ advocates that the nasion should be positioned no less than 15 mm and no more than 20 mm from the medial canthus.

Note

A 2–3 mm surgical change may be required in order to create the 'ideal' nasion position; a 4 mm change is rarely achievable or necessary.²⁶ For changes to the radix area, it is important to differentiate the nasal radix from the dorsum; in profile view, a horizontal line through the lateral canthus signifies the separation of the radix and dorsum. This helps determine the need for augmentation or reduction of the radix area. Radix augmentation often reduces the need for dorsal reduction.²⁶

Nasofrontal angle

The nasofrontal angle is formed by a line from nasion tangent to glabella and a line tangent to the nasal dorsum intersecting at nasion (Figure 14.23) (see Chapter 11). The normal value is 115–130° (tends to be more obtuse in women).

This angle may be used to analyse the relationship between the brow ridge and the nasal dorsum. The deepest point of the nasofrontal angle is **sellion** (or 'subnasion'), which usually lies just

below nasion; Natvig et al.³² state that nasion is approximately level with the superior palpebral fold (upper eyelid crease) and that sellion represents the **nasal starting point**. The nasal starting point in women should ideally be at or just below the level of the superior palpebral fold. In men, the nasal starting point should be at or just above the level of the superior palpebral fold.

Upper and lower components of the nasofrontal angle: The magnitude of the nasofrontal angle will depend on variations of the brow ridge and the nasal bridge; separation of the nasofrontal angle into upper and lower components will allow the glabella tangent-true horizontal plane (upper component) and the nasal dorsum tangent-true horizontal plane (lower component) angles to be assessed separately, as they *vary independently*. The nasofrontal angle may be separated into its upper and lower components by a true horizontal line through nasion. Normal values (Figure 14.23):

- Nasofrontal angle (upper component): 60–75°.
- Nasofrontal angle (lower component): 55°.

Note

Nasion is the *midpoint of the nasofrontal suture*. Locating skeletal nasion (N) is difficult clinically because of the overlying soft tissue in the nasal radix area, though the area may be palpated with a fingernail in order to feel the groove of the nasofrontal suture. Soft tissue nasion (N') is level with skeletal nasion. The landmark may also approximately be located as the point where a line tangent to both superior palpebral folds crosses the midline of the nasal radix, or slightly inferior to this point. The nasion is always superior to the level of the medial canthi and is above the deepest portion of the nasofrontal angle. In craniofacial anthropometry, the *deepest point of the nasofrontal angle* is termed **sellion** (or 'subnasion'), which is inferior and usually posterior to nasion; this is due to the often anterior curvature of the superior portion of the nasal bones. Where such a superior-anterior curvature of the nasal bones exists, it is sellion that is used as the nasal starting point (Figure 14.24). Nevertheless, most clinical articles and books continue to refer to this deepest point of the nasofrontal angle and nasal starting point as 'nasion'.

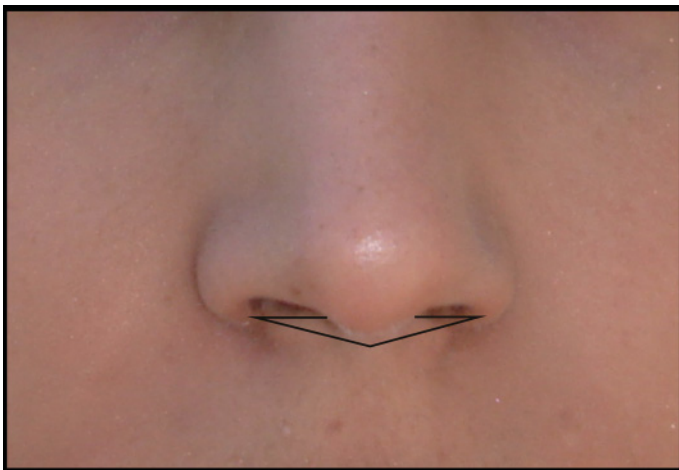
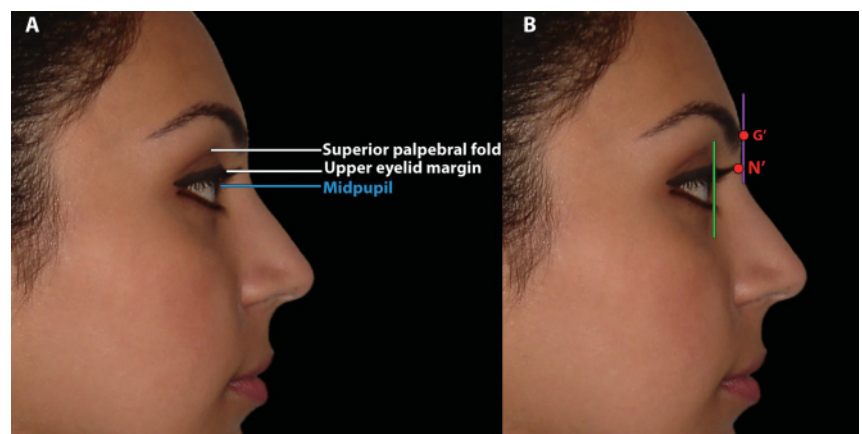


Figure 14.21 The columella-ala triangle.

Figure 14.22 Nasion position. (A) The nasion level or vertical position may be set between the superior palpebral fold and the eyelashes of the upper eyelid, 'ideally' about 2 mm above the lash line and 5 mm above the intercanthal line, although a lower level of the nasion, such as at the midpupil, may be acceptable. (B) The sagittal projection of nasion may be determined in relation to vertical lines tangent to the anterior cornea or glabella, or from the medial canthus.



Nasal dorsal evaluation

The morphology of the nasal dorsum (nasal bridge) is significant in nasal aesthetics, and nasal dorsal deformities account for perhaps the majority of patients presenting complaints.

- **Nasal dorsal line** (Figure 14.25): A line drawn from nasion (N') to the nasal tip (pronasale, Prn) forms the nasal dorsal line

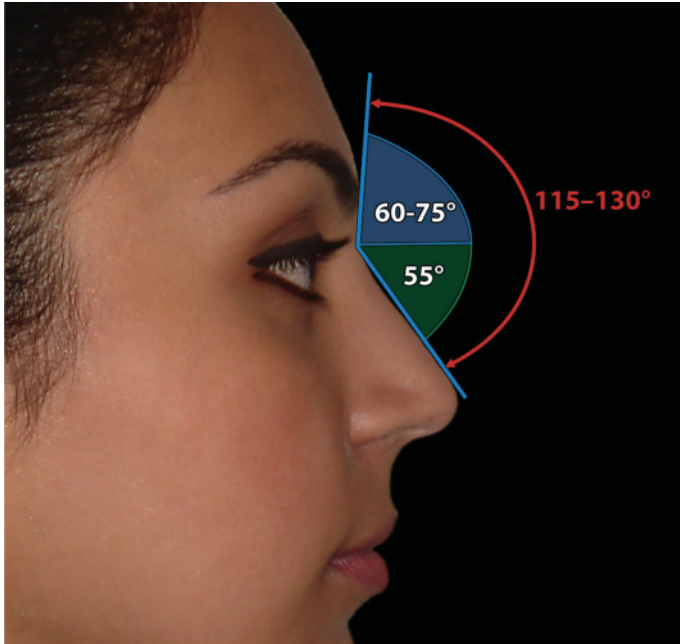


Figure 14.23 The nasofrontal angle and its separation into component parts by a true horizontal plane.

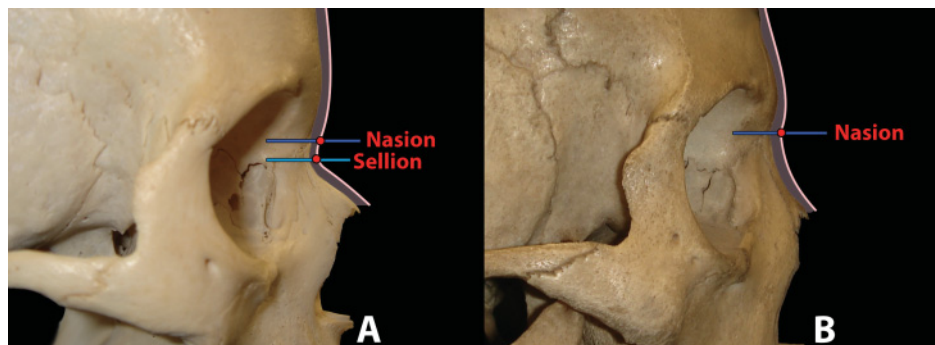


Figure 14.24 (A) Where an anterior curvature of the superior portion of the nasal bones exists, it is sellion that is used as the nasal starting point. Sellion is more inferior and posterior than nasion and is the deepest point of the nasofrontal region. (B) Where such a superior-anterior curvature of the nasal bones does *not* exist, nasion is used as the nasal starting point.

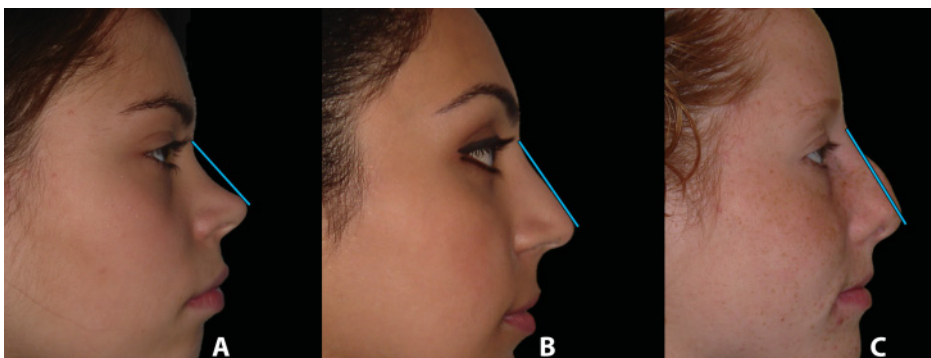


Figure 14.25 The nasal dorsal line is drawn from nasion (N') to the nasal tip (pronasale, Prn). (A) Nasal dorsum is basal. (B) Nasal dorsum almost parallel to and very slightly basal to the nasal dorsal line (up to 2 mm basal in women; approximately on the dorsal line in men). (C) Nasal dorsum is dorsal to the nasal dorsal line.

line. In the 'ideal' situation, the nasal dorsum should be almost parallel to and lie on or very slightly basal to the nasal dorsal line. In women, the nasal dorsum may be up to 2 mm basal and parallel to the dorsal line; in men, the dorsum is approximately on the dorsal line. If the nasal dorsum lies significantly basal to the nasal dorsal line, dorsal augmentation may be required; conversely, if the nasal dorsum is dorsal to the nasal dorsal line, nasal dorsal reduction may be indicated.

- **Nasal dorsal contour:** The contour of the nasal dorsum and dorsal line (N'-Prn) may be straight, convex or concave. Significant nasal dorsal *convexity* leads to a nasal 'hump' deformity, whereas nasal dorsal *concavity* leads to a 'ski slope' appearance. Excessively pronounced nasal dorsal concavity may lead to an unattractive 'saddle nose' deformity, often resulting from significant nasal trauma to the bony and/or cartilaginous dorsal framework; such patients require tissue augmentation to elevate the nasal dorsum.
- **Supratip break (or supratip breakpoint):** The nasal tip is the most anterior point of the nose (pronasale). The supratip area is just cephalic to the nasal tip, and represents the inferior portion of the nasal dorsum, where the lobule meets the dorsum. The supratip break or depression is a *subtle* dorsal depression formed by the convexity of the cephalic edges of the lateral crura as they diverge superolaterally over the cartilaginous nasal dorsum, higher than the nasal septum. It is a slight depression that exists on the aesthetic nose and helps to distinguish the dorsum from the tip; it is often more pronounced in the female.
- **Correlation of nasal dorsal plane to posterior auricular plane:** A weak correlation exists with the nasal dorsal plane

being almost parallel to the posterior auricular plane in women.

Nasal tip rotation

The concept of nasal tip rotation has been described by Simons (Figure 14.26).³³ Cephalic or caudal nasal tip rotation is along an

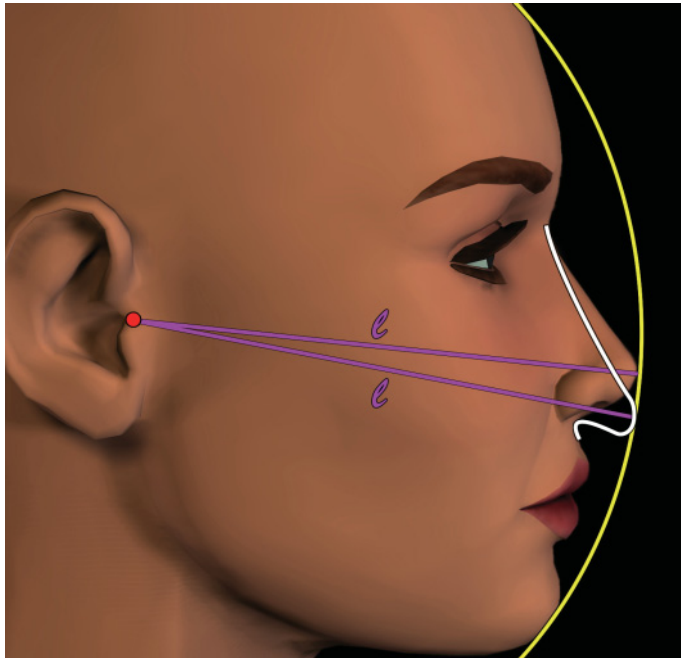


Figure 14.26 Nasal tip rotation: cephalic or caudal nasal tip rotation is along an arc, with the radius maintained. As the tip is rotated, there is the illusion of increased projection, although none exists. *L*, length. (After Simons.³³)

arc, with the radius maintained. As the tip is rotated, there is the *illusion of increased projection*, although none exists. However, nasal tip rotation *and* projection may occur together; the purpose of preoperative clinical evaluation is to distinguish the relative contribution of each to the presenting nasal deformity.

Nasal tip projection

Nasal tip projection describes an actual change in the distance from nasal ala to tip, i.e. the alar-tip distance. If there is increased tip projection, the nasal tip extends an excessive distance from the face and is perceived as disproportionately prominent. A number of methods have been described to evaluate sagittal nasal tip projection in profile view; each method has its limitations.

- **Nasofacial angle:** This is also termed the **frontal facial angle** or Jacques Joseph's **profile angle** (Figure 14.27).⁹ It is the inner angle formed by the intersection of the facial plane (glabella to pogonion) and the nasal dorsal plane (nasion to pronasale). If a nasal hump exists, it is transected by the dorsal plane, which must extend to the nasal tip.
 - **Ideal value:** 35° (range 30–40°).

Note

Jacques Joseph⁹ measured the 'profile angle' in portraits painted by various celebrated artists, such as Leonardo da Vinci, Thomas Gainsborough and Sir Joshua Reynolds; as such he determined an average profile angle of 30°, with a normal range of 23–37°. Joseph also developed a 'profilometer', in order to directly measure the profile angle without the need for a facial profile photograph (Figure 14.28).

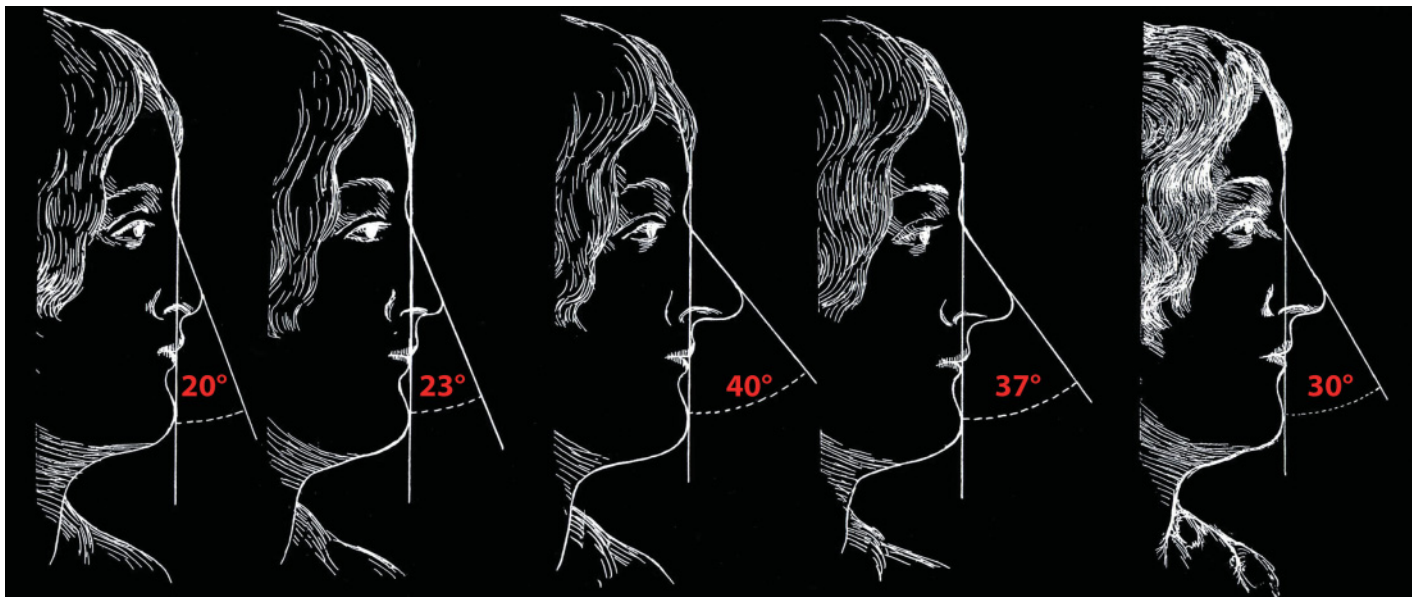


Figure 14.27 The nasofacial angle is the inner angle formed by the intersection of the facial plane (glabella to pogonion) and the nasal dorsal plane (nasion to pronasale). Jacques Joseph modified a drawing by Leonardo da Vinci to depict changes in this angle. (Modified from Joseph.⁹)

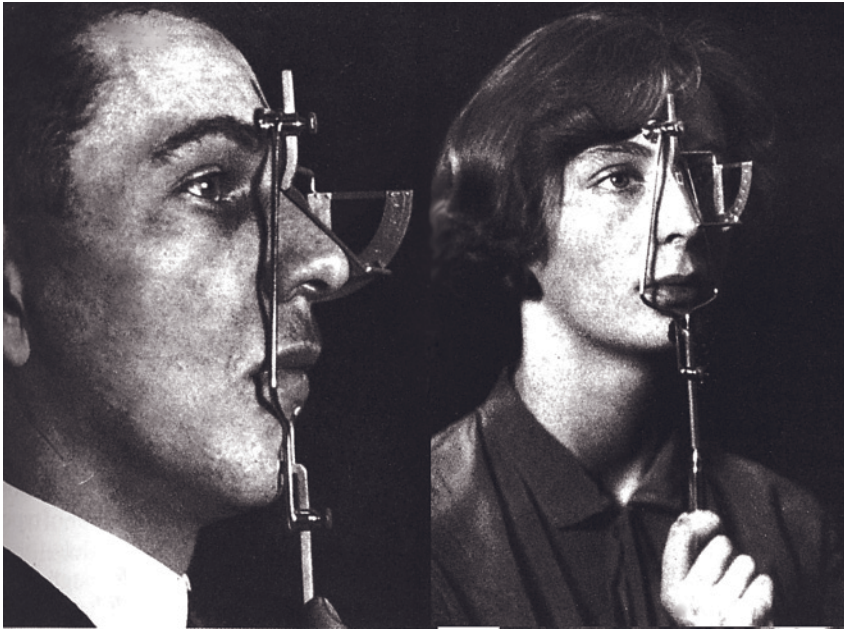


Figure 14.28 Joseph⁹ developed a profilometer to directly measure the 'profile angle' without the need for a facial profile photograph (assuming no nasal dorsal hump was present).

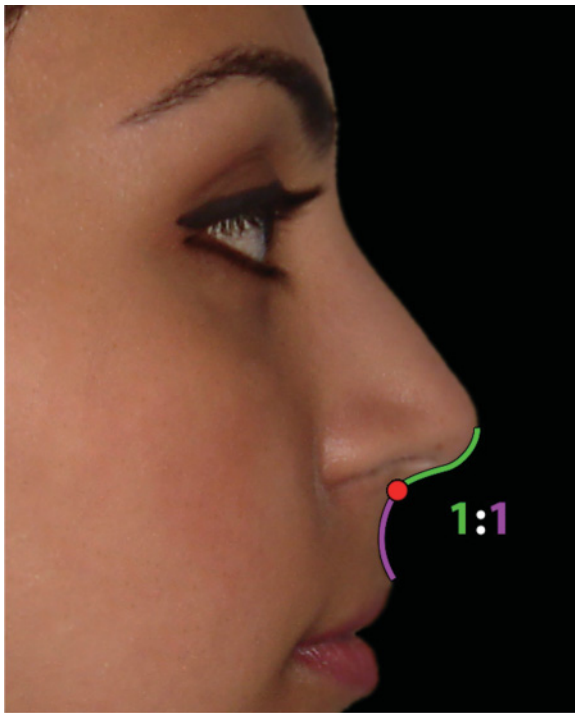


Figure 14.29 Nasal tip projection may be related to cutaneous upper lip height, i.e. the distance from the base of the columella to the nasal tip is in a 1:1 relationship with the height of the cutaneous portion of the upper lip (Simons method).³³

- **Tip projection relative to upper lip height (Simons method)** (Figure 14.29):³³ Nasal tip projection may be related to cutaneous upper lip height, i.e. the distance from the base of the columella (subnasale) to the nasal tip (pronasale) is in a 1:1 relationship with the height of the *cutaneous portion* of the upper lip (subnasale to upper lip vermilion border).

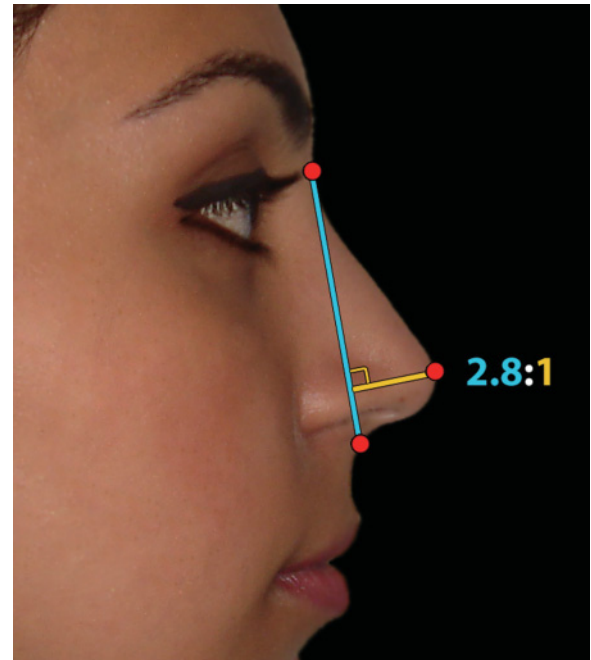


Figure 14.30 Nasal height to projection ratio: Baum³⁴ suggested a ratio of 2:1; Powell and Humphreys²³ suggest that a 2:1 ratio will result in excessive projection, and that the modified ratio of 2.8:1 is more accurate.

Individual variability in upper lip height must be borne in mind by the diagnosing clinician.

- **Nasal height to projection ratio (Baum method)** (Figure 14.30):³⁴ A vertical line is drawn from nasion (N') to subnasale (Sn); a horizontal line is drawn perpendicular to this N'-Sn line through the nasal tip (pronasale). The ratio of the vertical to the horizontal line, i.e. nasal height to projection ratio, is 2:1; Powell and Humphreys²³ suggest that a 2:1 ratio

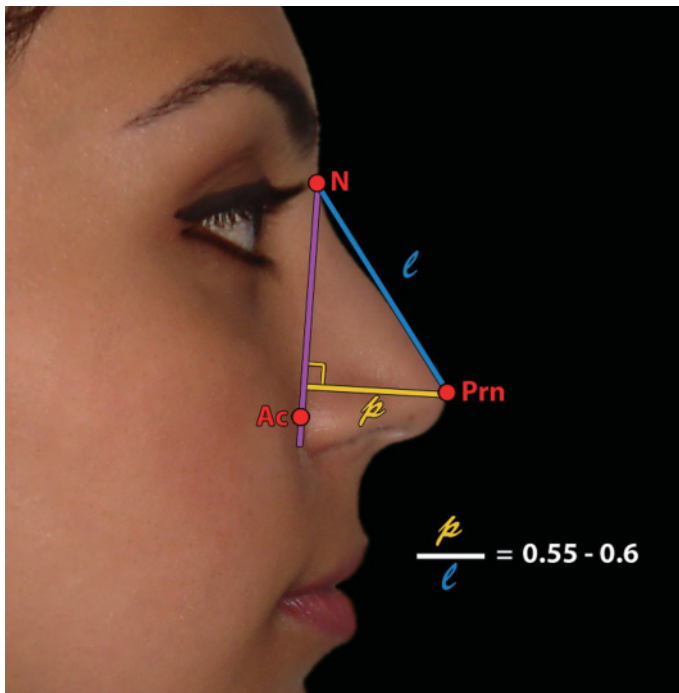


Figure 14.31 Nasal projection (p) to nasal length (l) ratio: Goode²³ suggested a nasal projection to length ratio of 0.55–0.6; in females the ratio is in the lower 0.5 range, and in males it is in the upper 0.5 range.

will result in excessive projection, and that the modified ratio of 2.8:1 is more accurate.

- **Nasal projection to nasal length ratio (Goode method)** (Figure 14.31):²³ Goode described an alternative vertical line, drawn from nasion (N') to the alar-facial crease (Ac); a horizontal line is drawn perpendicular to this N' -Ac line through the nasal tip (pronasale, Prn). The nasal dorsum length is then measured from nasion (N') to nasal tip (Prn). The ratio of the base of the created triangle (p) to the *dorsal line* (N' -Prn or 'l' for length) is 0.55 to 0.6; in females the ratio is in the lower 0.5 range, and in males it is in the upper 0.5 range.
 - $p/N'-Prn = 0.55-0.6$.
- **Nasal profile triangle method:** Crumley and Lancer (1988)³⁵ described the formation of a right angle triangle: nasion to pronasale to alar-facial crease, with the alar-facial crease (Ac) to pronasale side parallel to the Frankfort Horizontal (or ideally true horizontal) plane. Nasal projection (Ac-Prn) should be approximately 60% of nasal length (N' -Prn). This is similar to the Goode method.
- **Nasal projection to length ratio (Byrd)** (Figure 14.32):³⁰ Byrd (1993) postulates that the projection of the nasal tip and the nasal root are correlated with nasal length, and that nasal length is correlated with midfacial height. Thereby 'ideal' nasal length to tip projection ratio is 1.0:0.67, that is:
 - Nasal tip projection (Ac-Prn) is approximately two-thirds of nasal length ($N'-Prn$).
 - Nasal root projection (from corneal plane) is one-third of the nasal length.

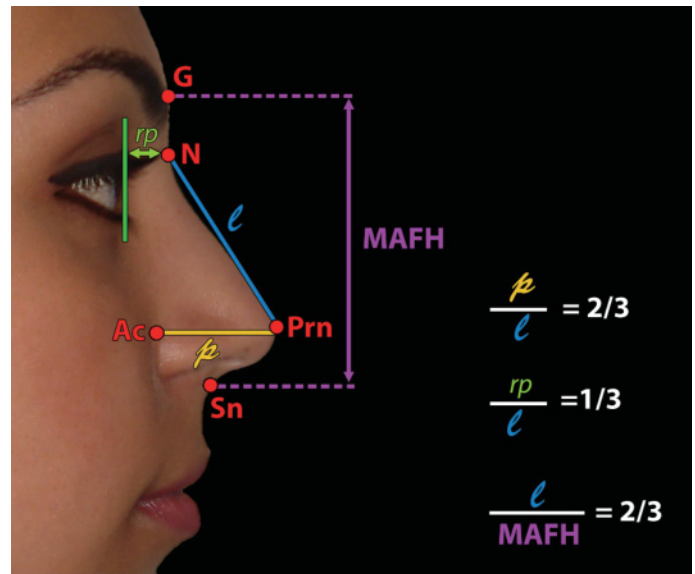


Figure 14.32 Nasal projections (tip and root) to length ratio (Byrd method).³⁰ MAFH, mid anterior facial height; rp , nasal root projection; l , nasal length; p , nasal tip projection.

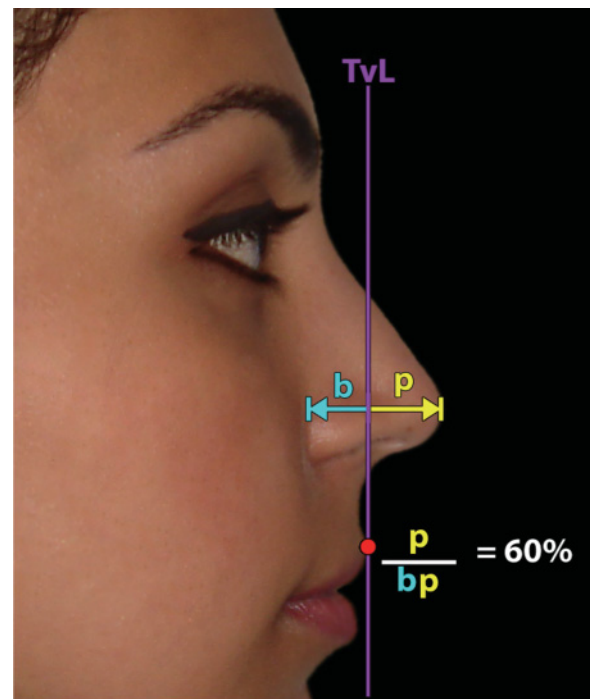


Figure 14.33 Nasal tip projection may be evaluated relative to the sagittal position of the upper lip (TvL: true vertical line through the most prominent position of the upper lip).

- Nasal length is approximately two-thirds of midfacial height (glabella-subnasale).
- **Tip projection relative to sagittal upper lip position** (Figure 14.33): Nasal tip projection may be evaluated relative to the upper lip position. A true vertical line may be drawn

tangent to the most anterior projection of the upper lip. Adequate nasal tip prominence is present when 50–60% of the horizontal projection of the nose lies anterior to the upper lip. If over 60% of the nose lies anterior to the upper lip, the nose is considered to be overprojected; if less than 50% of the nose is anterior to the upper lip, it is underprojected.

- **Facial circle method (Baud)** (Figure 14.34):³⁶ Baud (1966) described the ‘facial circle’ for analysing nasal projection in relation to the sagittal projection of the forehead and chin. The midpoint of the anterior semicircle was taken as the midpoint of the external auditory canal, but a better landmark is trignon, the notch on the superior border of the tragus (Behrbohm modification). A line from trignon to pronasale forms the radius of a circular arc; ideally, trichion (hairline) and pogonion (anterior projection of the chin) should be located on the path of this arc. Assuming normal forehead and chin position, if the nasal tip falls outside this circle it is considered to be overprojected.

Note

Nasal base projection: Leonardo’s square, described by Leonardo da Vinci, may be used to evaluate the sagittal position of the nasal base. The square is formed between the anterior superior point of the ear, the medial eyebrow, deepest point of the mentolabial fold and the angle of the mandible in profile view. The *alar base should fall within this square*; if the *alar-facial crease falls outside the square*, the nasal base is overprojected (Figure 14.35). Overprojection of the nasal tip may result from excessive projection of the **anterior nasal spine**, which pushes the caudal border of the nasal septum upwards. In such cases the upper lip is tethered and appears shortened, and the nasolabial angle is obtuse. Rees described the nose as appearing to ‘precede’ the face because of the prominent caudal septal border and nasal spine.³⁷

Nasal tip angle

The nasal tip angle was reintroduced by Farkas,³⁸ having been originally described by Jacques Joseph (‘septodorsal angle’) (Figure 14.36).⁹ It is the inner angle formed by the intersection of the columella tangent and the nasal dorsum tangent. According to Joseph,⁹ the ‘ideal’ nose has a 90° angle. Farkas³⁸ found a value of $73^\circ \pm 8^\circ$ in attractive women.

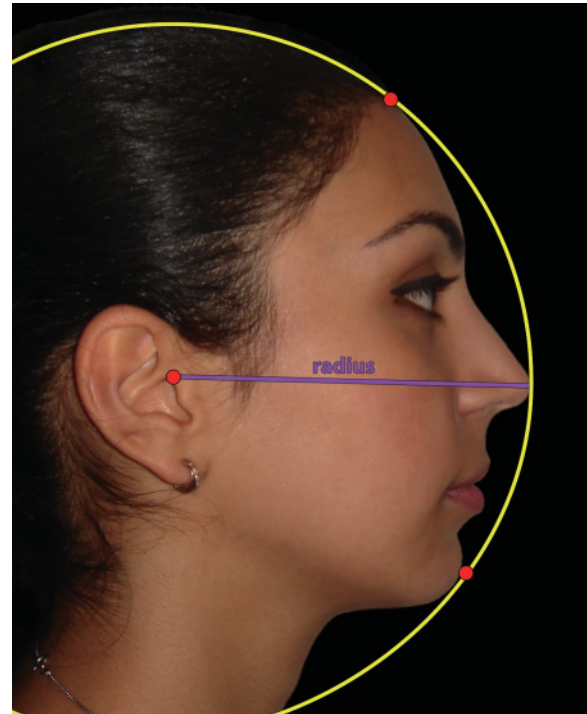


Figure 14.34 Baud’s ‘facial circle’: A line from trignon to pronasale forms the radius of a circular arc; ideally, trichion (hairline) and pogonion (anterior projection of the chin) should be located on the path of this arc. Assuming normal forehead and chin position, if the nasal tip falls outside this circle it is considered to be overprojected.



Figure 14.35 Nasal base projection: (A) Leonardo’s square, described by Leonardo da Vinci, may be used to evaluate the sagittal position of the nasal base. The *alar base should fall within this square*; if the *alar-facial crease falls outside the square*, the nasal base is overprojected. (Detail, *Study of Proportions and Study of Horsemen for the Battle of Anghiari*, Leonardo da Vinci, c. 1490, Gallerie dell’Accademia, Venice.) (B) The alar-facial crease falls outside the anterior part of Leonardo’s square, and the nasal base is overprojected.

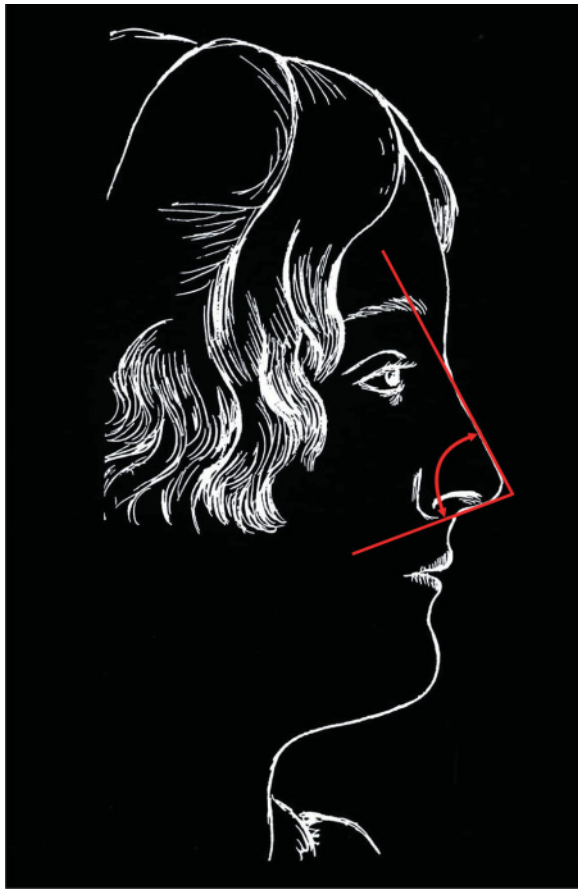


Figure 14.36 Nasal tip angle (Joseph's 'septodorsal' angle).⁹

Nasal tip support

The strength and support of the lower third of the nose may be evaluated by using fingertip depression to test nasal **tip recoil**.³⁹ The nasal tip is firmly depressed towards the upper lip and then released, allowing the tip to recoil. This is a reliable clinical test to evaluate the support of the mobile lower third of the nose, providing a dependable guide to the ability of the nasal tip to retain satisfactory support and projection following nasal tip refinement procedures.

Alar lobule to tip lobule relationship

The **ala to anterior (tip) lobule ratio** should be approximately 1:1; disproportion in the dimension of either the ala or the anterior lobule may result in an unattractive appearance. Bernstein⁴⁰ proposed that where disproportion exists, anterior lobular excess is more acceptable than alar excess.

Columella–alar relationship (profile view)

Columella double break

In layperson terminology the adjective 'retroussé' is used to refer to a person's nose that is turned up at the tip in an attractive way (from French *retrousser*: to roll up). This morphology of the

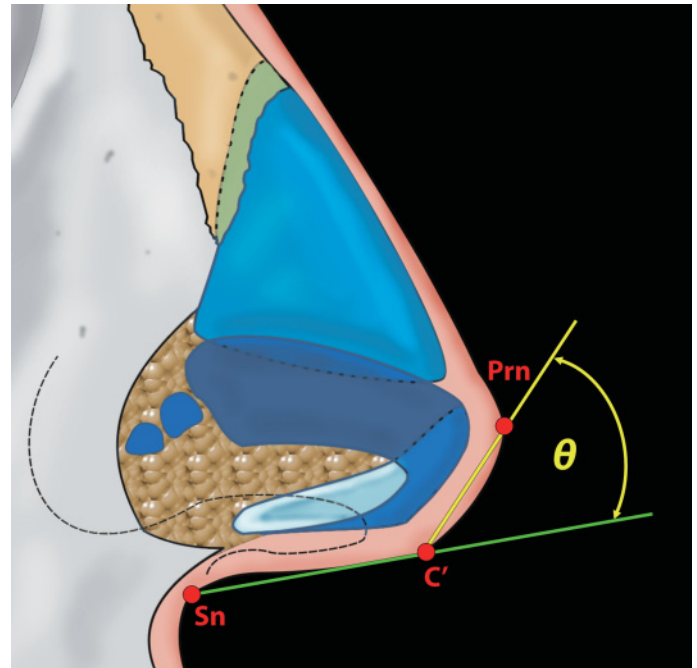


Figure 14.37 The 'ideal' columellar-lobular angle (θ) is 35–40° (C': columellar breakpoint).

nasal columella, particularly evident in profile view, is described clinically as a double break; it results from the curve of the medial crus at the columellar–lobular junction.

- **First breakpoint:** The point at which the nasal tip turns posteroinferiorly onto the infratip lobule; this is effectively at the nasal tip.
- **Second 'columellar' breakpoint (infratip breakpoint, C'):** A point at the mid-columella, where the columella takes a more horizontal course, extending posteriorly to subnasale. This point forms the **columella–tip lobule angle**, also termed the *columellar-lobular angle* (Figure 14.37).

Columellar-lobular angle

This is defined as the angle formed where the columella tangent and infratip lobule tangent intersect. The 'ideal' columellar-lobular angle is 35–40° (Figure 14.37).

Columella exposure

Approximately 2–4 mm of the columella should be visible below the alar margin in profile view. Greater than 4 mm of columellar exposure may be considered excessive, and may result from:

- Retracted alar lobule.
- Hanging caudal septum.

Columella–alar proportional relationship

Horizontal lines through the nasal tip, the highest point of the alar rims and the columella-lobular angle (columellar

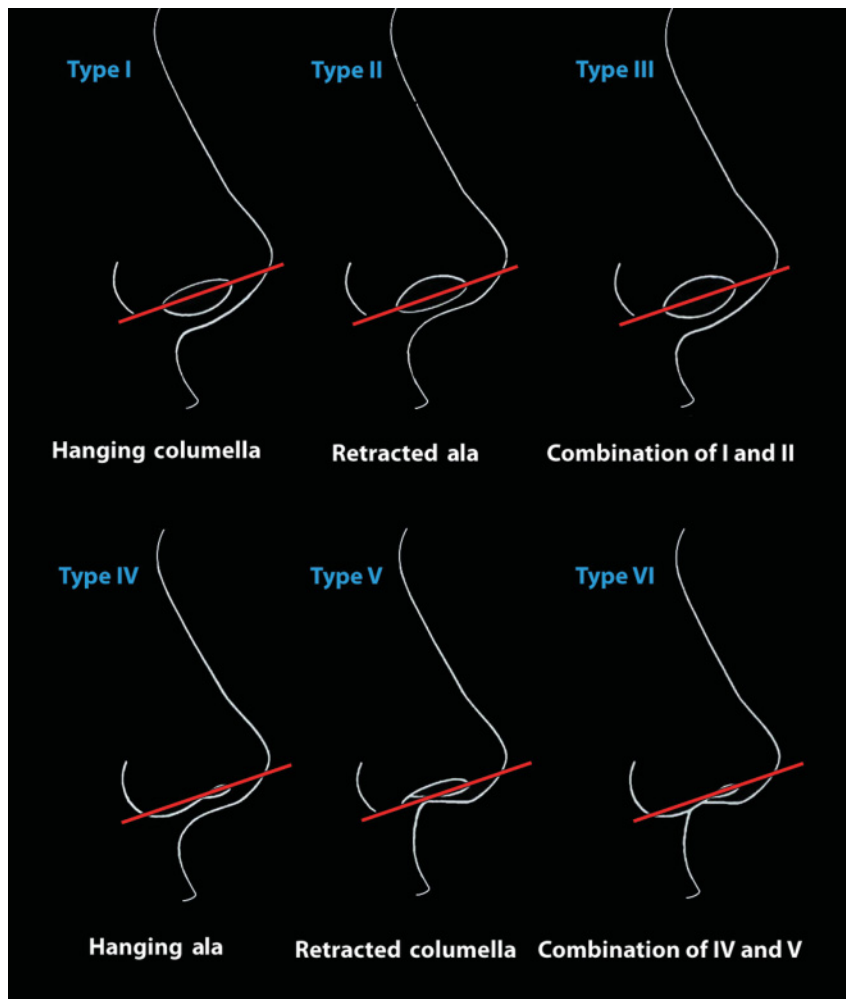


Figure 14.38 Columellar-alar relationship classification. (Redrawn from Gunter and Rohrich⁴¹ with kind permission of Wolters Kluwer Health.)

breakpoint) should divide the nasal tip into equal segments; this relationship is also evident in frontal view.

In profile view, the nostril is ovoid. The alar rim forms the upper half of the oval, and the lower half is formed by the columellar rim at the junction of the external and vestibular skin. A line drawn through the most anterior and posterior points of the oval represents the long axis of the nostril, and divides the oval into upper and lower halves. Gunter and Rohrich⁴¹ classified the columella–alar relationship into six types, by comparing the distance from the long axis to the alar rim superiorly and to the columellar rim inferiorly (Figure 14.38).

Nasolabial angle

The nasolabial angle, formed between the upper lip and the base of the nasal columella in profile view, has wide individual variability; it is the anterior inferior angle formed by the intersection of a line drawn from subnasale to labrale superius (upper lip tangent) and a line tangent to the nasal columella. Average values for Caucasians are:⁴²

- Male: $100^\circ \pm 12^\circ$.
- Female: $105^\circ \pm 10^\circ$.

Nasolabial angle (upper component) (Figure 14.39)

The nasolabial angle is formed by drawing a line tangent to the nasal columella (columella tangent) and a line tangent to the upper lip (upper lip tangent), intersecting at subnasale. This angle will depend on the inclination of the nasal columella and the upper lip. *To better evaluate the inclination of the nasal columella, the nasolabial angle may be separated into upper and lower component parts using a true horizontal line through subnasale.* This will allow the columella tangent-true horizontal plane and the upper lip tangent-true horizontal plane angles to be assessed separately, as they vary independently.

'Ideal' values for columella tangent to true horizontal plane are:

- Male: $10\text{--}15^\circ$.
- Female: $15\text{--}20^\circ$.

Note

Burstone has postulated that an obtuse nasolabial angle resulting from an increased columellar inclination is more aesthetically acceptable than that resulting from a retrusive upper lip.⁴³

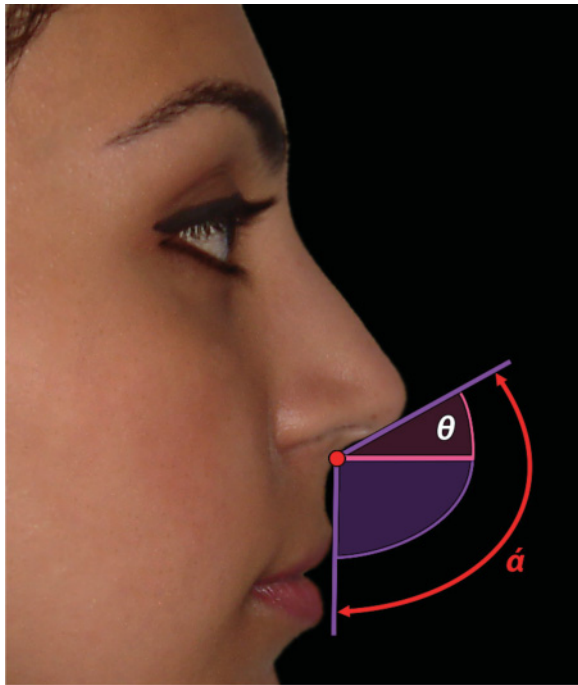


Figure 14.39 Nasolabial angle (upper component θ): Male: 10–15°; female: 15–20°. Nasolabial angle (α): Male: 100° ± 12°; female: 105° ± 10°.

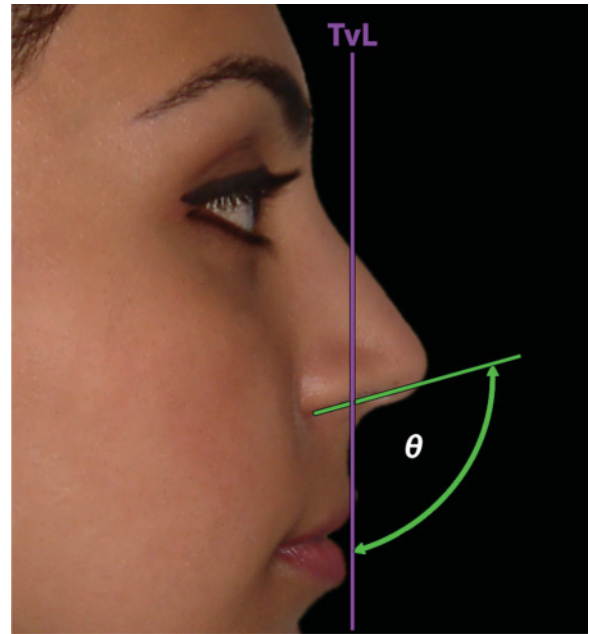
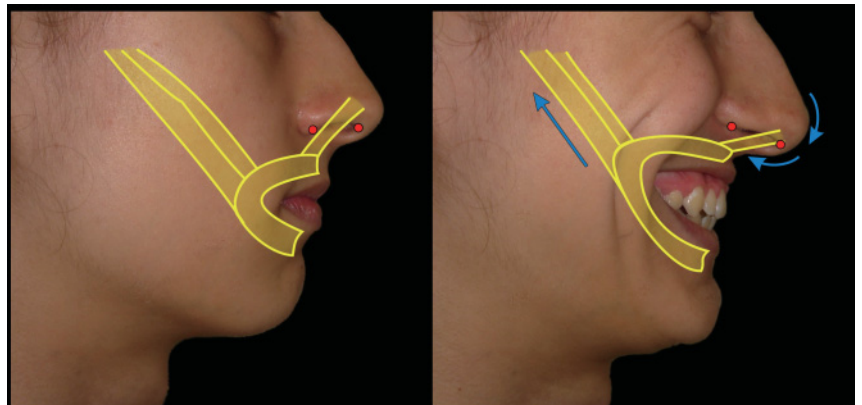


Figure 14.40 Nasal base inclination (θ): Male: 90–95°; female: 95–105°.

Figure 14.41 Dynamic nasolabial evaluation. A profile smiling view may demonstrate caudal displacement of the nasal tip from overactive depressor septi nasi and nasalis muscles, via the contraction of the zygomaticus and orbicularis oris muscles.



Note

Nasal base inclination (Figure 14.40): If there is a hanging columella or retrusive upper lip, rather than the nasolabial angle it is possible to measure the inclination of the nasal base by the intersection of a line through the most anterior and posterior edges of the nostril with a true vertical line through subnasale. Some authorities refer to this measurement as the ‘nasolabial angle’ or ‘columella inclination’, both of which are inaccurate as the upper lip and columella are not involved in the measurement. Normal values are:⁴⁴

- Male: 90–95°.
- Female: 95–105°.

Dynamic nasolabial evaluation

The relationship between the nasal tip lobule and the upper lip on *smiling* should be evaluated. The zygomaticus muscles exert an upward and backward pulling effect on the orbicularis oris, which in turn exerts a downward and backward pulling effect on the muscles of the lower nose, particularly the overactive depressor septi nasi muscles and to some extent the nasalis. In some cases this may lead to significant caudal rotational displacement of the nasal tip (Figure 14.41).³⁷

Basal evaluation

External nasal morphology in basal view has been described as ‘ideal’ if circumscribed by an equilateral (or ‘mildly’ isosceles) triangle with the columella at its centre (Figure 14.42).^{14,40}

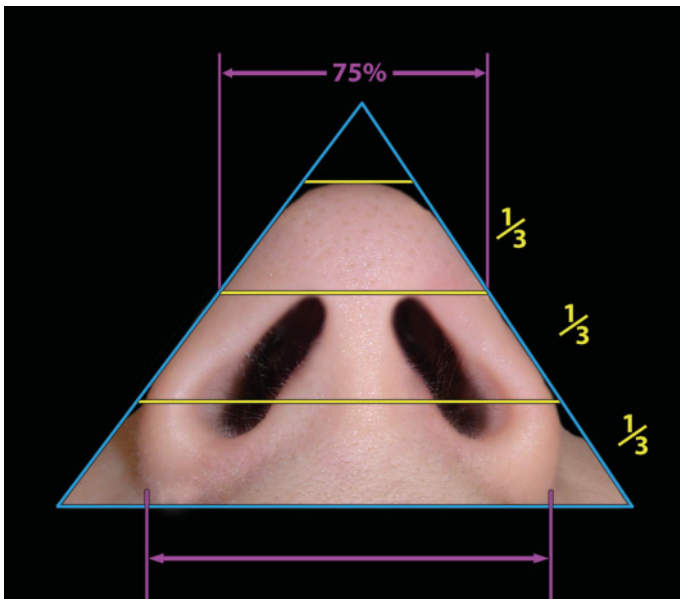


Figure 14.42 Nasal evaluation in basal view.

Columella (basal view)

The middle portion of the nose in basal view may be divided into three segments, each approximately equal in dimension (Figure 14.42):

- **Tip (anterior) lobule:** The anterior or tip lobule is not strictly speaking part of the columella, but is the infratip lobule viewed from below, and is the anterior projection from the columella. It is approximately one-third of the length from the nasal base to the nasal tip, and 75% of the width of the alar base.
- **'Intermediate' columella:** This is the narrowest part of the columella; the term 'columella' usually refers to this segment.
- **Basal columella:** The columella flares towards its base, which conforms to the shape of the medial crura.

Nares (nostrils, basal view)

There is considerable variation in nostril shape,³⁸ but within each individual the nostrils should be symmetrical (Figure 14.43). The 'ideal' Caucasian nostrils are oval or pear-shaped, widest at the nostril sill (the skin forming the base of the nostril).

- **Nostril width:** This should be approximately equal to columellar width (5–10 mm on average).
- **Nostril length:** Caucasian nostrils are approximately 15–20 mm in length.
- **Nostril long axis:** The orientation of the long axis of the nares should be between 45° and 60° to the columella.

Relative nasal relationships – evaluation

Perceived nasal attractiveness depends to a great extent on the size, shape and position of the nose *relative* to its neighbouring

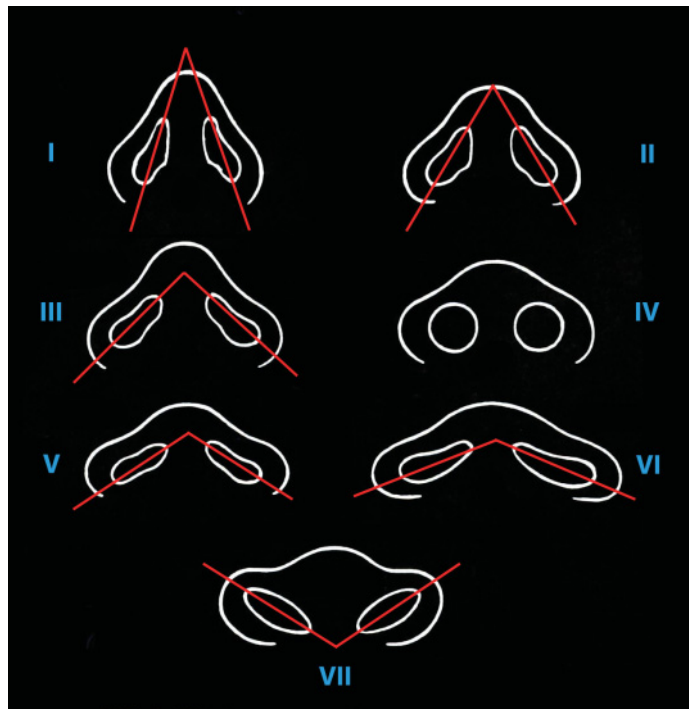


Figure 14.43 Nostril types. Types I–III are most frequently observed in Caucasians. Types IV–VII are more common in other ethnic groups. The nostril axes are anteriorly convergent in types I–VI, but anteriorly divergent in type VII. (Redrawn from Farkas et al.,³⁸ with kind permission of Springer Science+Business Media.)

structures. Therefore, *the 'ideal' nose varies for every patient*. Of the five facial prominences already described (i.e. the forehead, nose, lips, chin and submental region) the nose is literally the most prominent, dominating the facial profile.

Nasal-forehead/brow ridge relationship

The morphology of the forehead and the prominence of the brow ridge influences perceived nasal attractiveness. Forehead contour may be *posteriorly inclined*, *vertically flat* or *anteriorly inclined and protruding*. A posteriorly inclined forehead tends to exaggerate the appearance of nasal length and projection; conversely, a flat or protruding forehead reduces the appearance of nasal length.

Excessive anterior projection of the brow ridge (frontal bossing) may make the nasal radix *appear* depressed and the nasofrontal angle acute, giving the nose the appearance of excessive projection.

Nasal-upper lip relationship

Reduced prominence of the upper lip may result from reduced dentoalveolar or maxillary skeletal support for the upper lip (e.g. maxillary hypoplasia or maxillary dentoalveolar retrusion), from significantly thin soft tissue of the upper lip or excessive retroclination and retraction of the maxillary incisor teeth from poorly executed orthodontic treatment. The resultant **retrusive upper lip** will result in the *appearance* of excessive nasal projection.

Note

Nasal growth has a strong genetic determination, and nasal morphology is often 'typical' in a family. In some orthodontic patients retraction of the maxillary incisors may be a requirement. Excessive nasal growth occurring concomitantly in such patients will be detrimental to facial profile aesthetics. In patients in whom excessive nasal growth is either present or is predicted, the orthodontist should not be deterred from carrying out the necessary orthodontic treatment; discussion with the patient regarding the need for subsequent rhinoplasty is the ideal approach.

Nasal-lip-chin relationship

The relationship of the nose to the chin is vitally important. Inadequate sagittal chin projection will create the appearance of excessive nasal projection. A number of analyses may be used to evaluate the relationship of the nose to the chin and the lips, such as the S-line, E-line and nasal projection to the H-line of Holdaway (see Chapters 17 and 20).

Nasal-submental region relationship

Greer et al.⁴⁵ found a strong nasal to cervical relationship, whereby the perceived appearance of the nose was affected by the contour of the neck (see Chapter 21).

Normative values for nasal dimensions

Farkas (1994)^{38,42} has provided normative values for nasal dimensions from white Caucasian, Chinese and black American population samples (Table 14.2). In comparison to white Caucasian individuals, Chinese and black individuals generally have:

- Reduced nasal length (N'-Prn).
- Reduced nasal projection.
- Increased alar base width.
- Acute nasofacial angle.
- Broader nasal tip.
- Thicker nasal skin.

Nasal function

The nose is for respiration. The design of the nasal apparatus serves to warm, humidify and partly filter the inspired air. The olfactory receptors are also placed in the nose, as odours are airborne, and mediate the sense of olfaction. *Nasal function is intimately related to nasal form.* Therefore, the aim of a successful rhinoplasty is both to improve aesthetics and to maintain, or where necessary improve normal nasal function.

Functional evaluation of the nose involves examination of the nasal valves (nasal airflow is regulated by the internal and external nasal valves), the nasal septum, turbinates and any evident pathology.

Table 14.2 Normative values for adult nasal dimensions and parameters

Nasal dimension	White Caucasian				Chinese				Black (American)			
	Male		Female		Male		Female		Male		Female	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Linear values (mm)												
Nasal root width	20	2	18	2	20	2	20	1	23	3	21	2
Nasal alar width (Al-Al)	35	2	31.5	2	39	3	37	2	44	3.5	40	3
Alar base width (Ac-Ac)	33	2	30.5	2	38.5	2	36.5	2	40	4.5	38	3.5
Mid-columellar width	7	1	7	1	8	0.5	7	1	8	1	7.5	1
Nasal height (N'-Sn)	55	3	51	3	53.5	3	52	3	52	3	49	4
Nasal length (N'-Prn)	50	4	45	3	46	3	44	4	46	3.5	43	4
Nasal tip projection (Sn-Prn)	20	2	20	2	16	1.5	15	2	18	2	16	2
Alar thickness	6	1	5	1	7	1	7	1	7	1	6.5	1
Angular values (degrees)												
Nasofrontal angle	130	7	134	7	135	7	135	4	127	12	128	8
Nasolabial angle	100	12	104	10	87	12	89	11	72	15	74	15
Nostril axis inclination	58	9	64	7	34	10	32	11	24	8	25	12

Modified from Farkas.^{38,42}

- **Internal nasal valves:** These are formed by the junction of the caudal margin of the upper lateral cartilages and the nasal septum; they are the *most important regulator* of nasal airway resistance. The internal valve is the narrowest portion of the upper airway, narrowing on gentle inspiration and widening on gentle expiration. The caudal border of the upper lateral cartilage should flare away from the septum by a minimum angle of 10–15° in order to maintain internal valve patency.

Note

The **Cottle test** may be used to evaluate internal valve abnormality or obstruction. A finger is used to draw the cheek and lateral nasal wall laterally, carrying the upper lateral cartilage away from the septum, thereby opening the angle of the ipsilateral internal nasal valve. If nasal airflow is improved on the tested side, the **Cottle sign** is positive, indicating an abnormality of the nasal valve.³⁷

- **External nasal valves (nostrils):** These are formed by the lateral aspect of the alar cartilages; collapse of the nostril on gentle inspiration indicates abnormality of the external nasal valve. This is a common iatrogenic problem, seen in patients having had excessive trimming of the lateral crura of the alar cartilages.
- **Nasal septum:** Septal deviation is very common and may *occasionally* warrant correction. Deflections may be observed using a nasal speculum.
- **Turbينات (nasal conchae):** Enlargement of the inferior turbinates may lead to nasal obstruction. Application of vasoconstrictors to the turbinates provides temporary shrinkage; if this results in relief of symptoms, the cause of the breathing difficulty has been diagnosed.

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Chapter 15 The Malar Region

Introduction

One of the most recognizable features of the midface is the contour and prominence of the superior-lateral part of the cheek, termed the **malar eminence** or 'cheekbone', formed by the underlying zygomatic bone. The malar eminence is a recognized characteristic of facial attractiveness (Figure 15.1). Malar hypoplasia or deficiency is due to lack of projection of the body of the zygomatic bone.

Terminology

- Malar (from modern Latin *malaris*, from Latin *mala*: 'jawbone' or 'cheekbone').
- Zygomatic (from Greek *zugoma*, from *zugon*: a 'yoke' or 'join').
- Jugal (from Latin *jugalis*, from *jugum*: a 'yoke' or 'join'; also Latin *jungere*: 'to join').
- Os (Latin: 'a bone').

A number of terms may be used to describe the layperson's term 'cheekbone'. The terms **malar bone**, **zygomatic bone**, **zygoma** and **os jugale** are often used interchangeably, although there is only one term for the **zygomatic arch**. The term 'zygomatic' is derived from the Greek and Latin words for a 'yoke', which is a wooden crosspiece fastened over the necks of two animals and attached to a plough or cart that they pull. Moreover, a pair of animals may be thus 'yoked' together. The derivation is

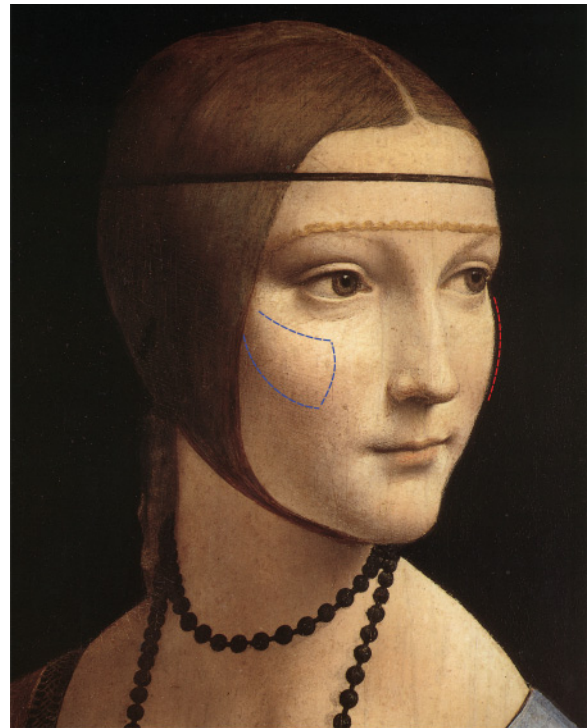


Figure 15.1 The malar eminence is an important aesthetic feature of the face, forming the contour and prominence of the superior-lateral part of the cheek. (Modified, detail, *Lady with an Ermine*, portrait of *Cecilia Gallerani*, Leonardo da Vinci, c. 1485, Czartoryski Museum, Kraków.)

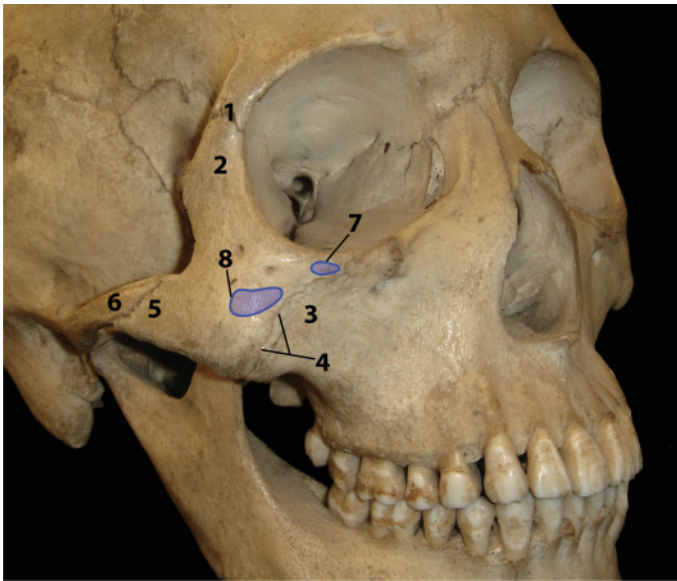


Figure 15.2 Anatomy of the zygomatic bone:

- 1 Frontozygomatic (FZ) suture
 - 2 Frontal process of the zygomatic bone
 - 3 Zygomatic process of the maxilla
 - 4 Zygomaticomaxillary suture
 - 5 Temporal process of the zygomatic bone
 - 6 Zygomatic process of the temporal bone
 - 7 Zygomaticus minor (origin)
 - 8 Zygomaticus major (origin)
- } Zygomatic arch

presumably due to the joining together of various skeletal structures by the zygomatic bone, and the modest resemblance of the bizygomatic region in frontal view to a yoke.

Anatomy

The anterior and slightly convex lateral surface of the **zygomatic bone** forms the bony prominence of the upper cheek, also termed the **malar eminence**; in layperson's terms, this is the cheekbone (Figure 15.2). It is perforated by the zygomaticofacial foramen. Two important muscles of facial expression, particularly important for smiling, arise from the zygomatic bone. Zygomaticus major arises from the anterolateral surface of the zygomatic bone, and zygomaticus minor from just superior to the zygomaticomaxillary suture. Together with a number of smaller muscles, these muscles cause a superior and lateral movement of the midfacial soft tissues associated with smiling and the expression of joy.

The **zygomatic arch** is formed by the zygomatic process of the temporal bone and the temporal process of the zygomatic bone. Anteriorly, the superiorly projecting **frontal process of the zygomatic bone** and the **zygomatic process of the maxilla** may be considered as the anterior pillars of the arch. The zygomatic process of the maxilla is palpable through the soft tissues of the cheek and intraorally in the buccal sulcus.



Figure 15.3 Right-sided malar deficiency in a patient with hemifacial microsomia.

Clinical evaluation

The zygomatic region must be clinically evaluated for:

- **Proportional relationships:** This is particularly important in terms of the bizygomatic width in relation to face height, bitemporal and bigonial widths.
- **Bilateral symmetry:** It is important to evaluate the symmetry of the left and right sides in frontal, profile and superior views (Figure 15.3).
- **Malar position:** The vertical position of the malar eminence in relation to the face and the soft tissues of the cheek.
- **Malar prominence:** The sagittal projection of the body of the malar bone, which is an important parameter in facial aesthetics.

The relationship of the malar regions to the rest of the patient's face must be evaluated in frontal, oblique lateral and left/right profile views. It is useful to analyse the malar region from above and behind (superior view), and from below (inferior view). In addition, it is particularly useful to evaluate malar projection, or lack thereof, from a superior oblique lateral view (Figure 15.4). Photographic records may be taken of all these views.

Bizygomatic width

The bizygomatic width should be the widest region of the face in frontal view. The bizygomatic width and its relation to the facial height, bitemporal width and bigonial width have a significant influence on overall facial form (Table 15.1).

The facial height to width ratio (facial index) gives the overall facial type, such as 'tall' or 'short' or 'square' face. The proportionate facial height (nasion-menton) to bizygomatic width ratio is approximately 90% for men and 85% for women.

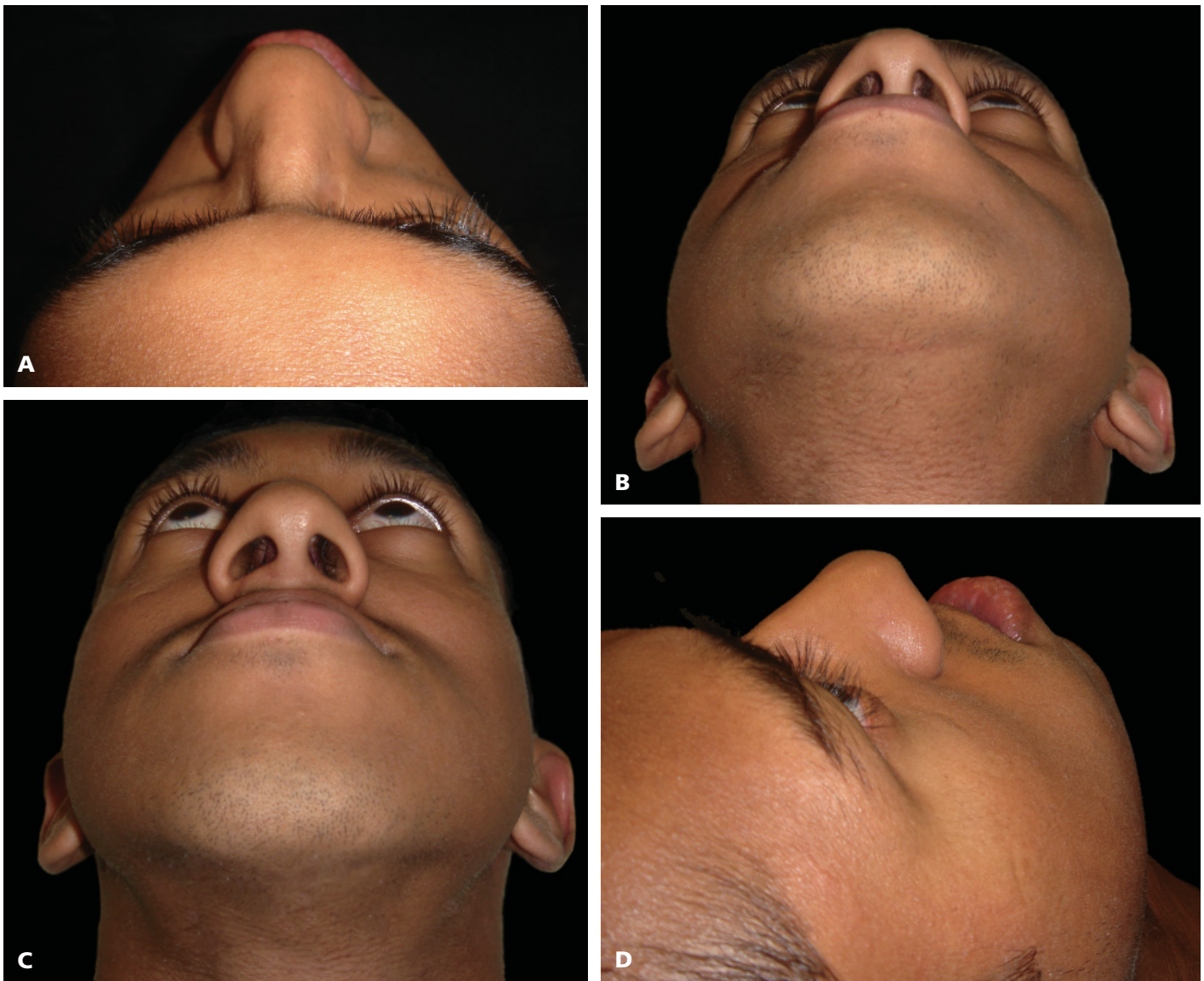


Figure 15.4 Evaluation of malar region: (A) superior view; (B) inferior view; (C) oblique inferior view; and (D) superior oblique lateral view.

Table 15.1 Facial widths and total face height in white Caucasians

	Male (mm)	Range (mm)	Female (mm)	Range (mm)
Bitemporal width (Ft'-Ft')	115	111-121	110	108-116
Bizygomatic width (Zy'-Zy')	140	134-144	130	125-135
Bigonial width (Go'-Go')	105	99-113	95	90-100
Face height (N'-Me')	125	119-130	110	107-116
Total face height (Tr-Me')	190	175-199	170	165-181

Normative values based on original data from Farkas.¹

Note

When describing face height, it is important to clarify the landmarks used for measurement (see Figure 8.4):

- **Face height:** The clinical term 'face height' usually refers to the height of the middle and lower face, measured from glabella or soft tissue nasion to soft tissue menton. In anthropometry this is termed the **morphological face height**. This is the face height used in calculating the **facial index**, which is a numerical expression of the ratio between the facial height (nasion to menton) and the bizygomatic facial width (zygion to zygion) of a living person (see Chapter 8 for more details).
- **Total face height:** The clinical term **total face height** (TFH) refers to the height of the face from the hairline (trichion) to soft tissue menton. In anthropometry this is termed the **physiognomical face height**.
- **Craniofacial height:** This is the height of the head and is measured from vertex to soft tissue menton.

Bizygomatic facial width, measured from the most lateral point of the soft tissue overlying each zygomatic arch (zygion, Zy'), is approximately 70–75% of *total* vertical facial height (trichion-menton). *The bizygomatic distance should be the widest part of the face.* **Bitemporal width**, measured from the most lateral point on each side of the forehead (frontotemporale, Ft'), is 80–85% of bizygomatic width. **Bigonial width**, measured from the soft tissue overlying the most lateral point of each mandibular angle (soft tissue gonion, Go'), is usually 70–75% of bizygomatic width (see Figure 8.4).

Note

Relativity and the three lateral facial promontories:

The absolute values of bitemporal, bizygomatic and bigonial width are not as important as their relative widths described above, which essentially correspond with the widths of the upper, middle and lower face. Facial disproportion may result if any of these widths are too narrow or too wide in comparison to the others, e.g. increased bigonial width in 'short face' patients, or those with **masseteric hypertrophy**, or increased bitemporal width in certain craniofacial syndromes, will disrupt normal facial proportional relationships (see Figure 11.4).

Malar augmentation may be required in patients with malar or malar-maxillary hypoplasia. Moreover, patient with tall, thin faces may appear more attractive with malar augmentation as the transverse facial disproportion between the width of the forehead, midface and mandible is corrected. Patients with very round, full faces may also benefit from malar augmentation, providing more definition in the malar region.

Malar position

The malar eminence lies just inferior and lateral to the orbital rim on the skull and is located 15–20 mm inferior to the lateral

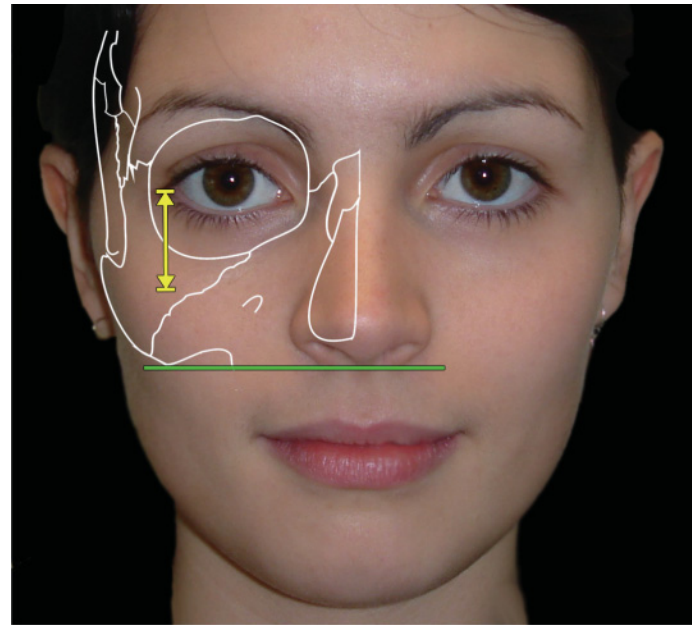


Figure 15.5 The malar eminence is located 15–20 mm inferior to the lateral canthus of the eye and its inferior most aspect is almost in line with the base of the nose.

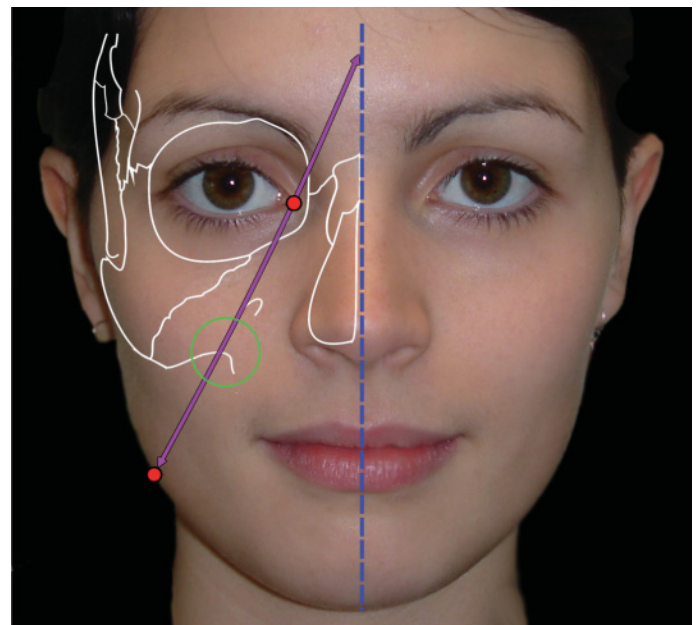


Figure 15.6 The mild depression of the cheek, which is just inferior and medial to the malar eminence, is roughly midway along a diagonal line drawn approximately 30° to the facial midline, from the medial canthus of the eye to the gonial angle.

canthus of the eye on the face. The inferior most aspect of the malar eminence is almost in line with the base of the nose (Figure 15.5). In frontal view, the mild depression of the cheek, which is just inferior and medial to the malar eminence, is roughly midway along a diagonal line drawn approximately 30° to the facial midline, from the medial canthus of the eye to the gonial angle (Figure 15.6).



Figure 15.7 Malar deficiency.

Height of malar contour

The height of contour of the malar region, i.e. the most superior extension of the soft tissue contour of the malar eminence, is located inferior and lateral to the lateral canthus of the eye in frontal view and inferior and anterior to the lateral canthus of the eye in profile view.

Malar projection and sagittal contour

In frontal and profile view, the contour of the malar eminence may be described as:

- Normal: which implies a degree of convexity and prominence.
- Flat: which implies sagittal and/or lateral deficiency, i.e. inadequate prominence (Figure 15.7).
- Excessively prominent: which implies greater than average sagittal and/or lateral prominence.

Note

Malar deficiency/flatness tends to be well correlated with sagittal maxillary deficiency.

Palpation of the malar region helps relate the soft tissue contour to the underlying bony morphology (Figure 15.8).

Area of maximal malar projection

Malar deficiency tends to vary from one individual to another. Several different techniques have been described to locate the area of maximal projection of the malar eminence. This is particularly important when planning placement of an implant for malar augmentation. The different techniques described to locate the area of maximal projection of the malar eminence are:

- **Hinderer's crossed lines** (Figure 15.9): A line is drawn from the lateral canthus of the eye to the oral commissure, and this is crossed by the alar-tragal line. Hinderer suggested that malar augmentation should be undertaken by placement of



Figure 15.8 Palpation of the malar region helps relate the soft tissue contour to the underlying bony morphology.

an implant in juxtaposition to the crossed lines in the upper and outer quadrant.²

- **Wilkinson's method** (Figure 15.10): This method suggests locating the maximum malar prominence at or just lateral to the lateral canthus on an area approximately one third of the distance from the lateral canthus to the inferior border of the mandible.³
- **Silver's malar prominence triangle** (Figure 15.11): Silver⁴ suggests drawing a malar prominence triangle. A vertical line is dropped from the lateral limbus with the patient looking ahead (the purple line in Figure 15.11). A horizontal line is drawn midway between the vermillion border of the upper lip and subnasale (the blue line). These lines meet at point X. A line is drawn from point X to the medial canthus (the right green line). The angle formed between this right green

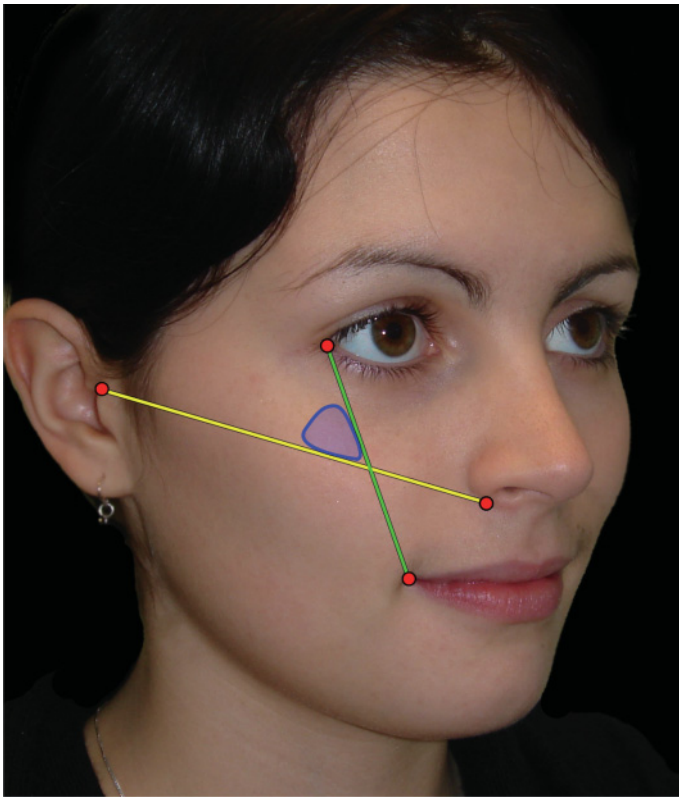


Figure 15.9 Hinderer's crossed lines.

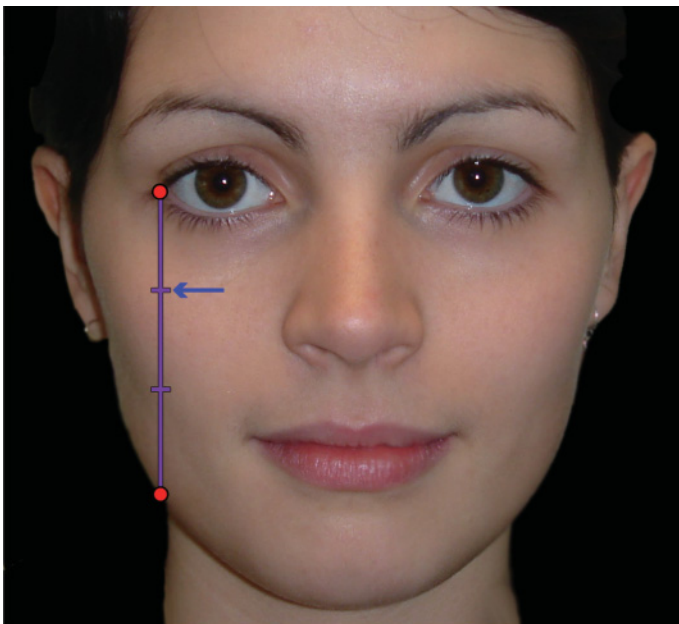


Figure 15.10 Wilkinson's method.

line and the vertical purple line is reflected laterally to form the left green line (X-P). Where the Frankfort Horizontal plane crosses this line, at point P, is the malar prominence.

- **Powell's analysis** (Figure 15.12): Powell et al.⁵ attempted to determine the malar prominence using three-dimensional

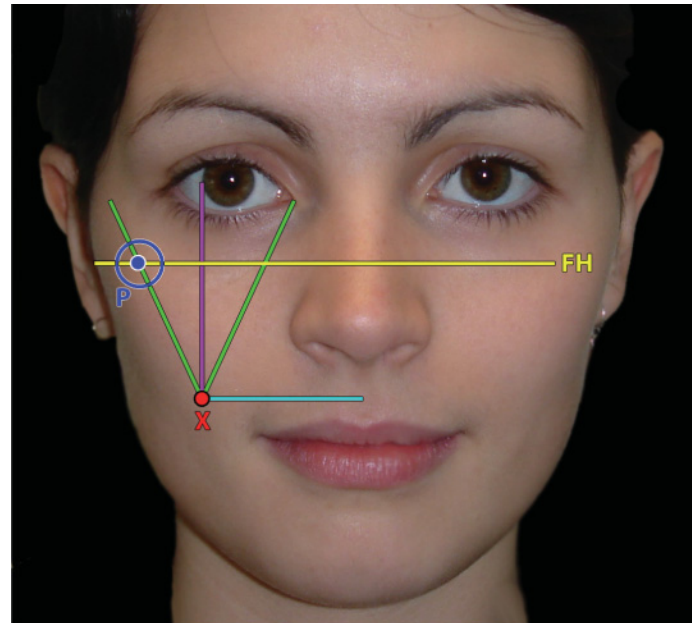


Figure 15.11 Silver's malar prominence triangle. FH, Frankfort Horizontal plane.

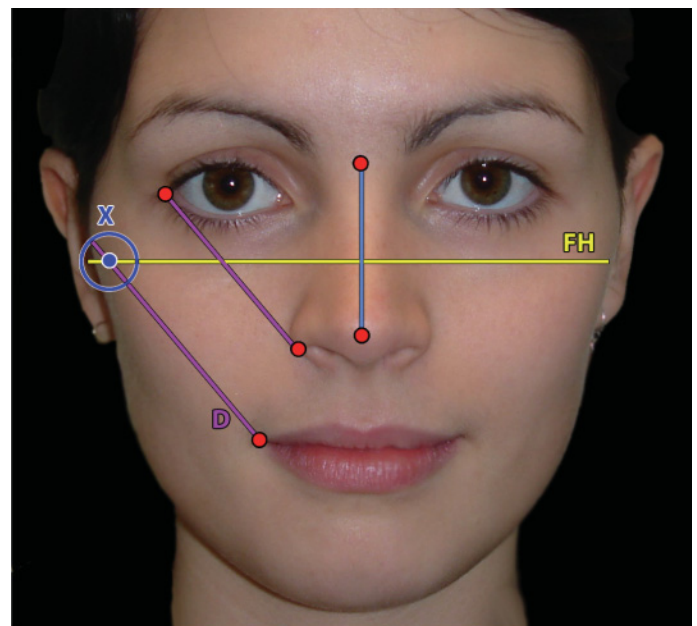


Figure 15.12 Powell's analysis.

reconstructions of computed tomography (CT) scans. They found that the height of the contour vertically was at or slightly below the Frankfort Horizontal plane on the bony skeleton. The FH plane bisects the midnasal line (nasion to pronasale, the blue line in Figure 15.12). Another line is drawn from the ala to the lateral canthus (upper pink line), and a 'line D' parallels this line, running through the oral commissure. Where line D crosses the FH plane at point X is the malar prominence, approximately 15–20 mm lateral to the lateral canthus.

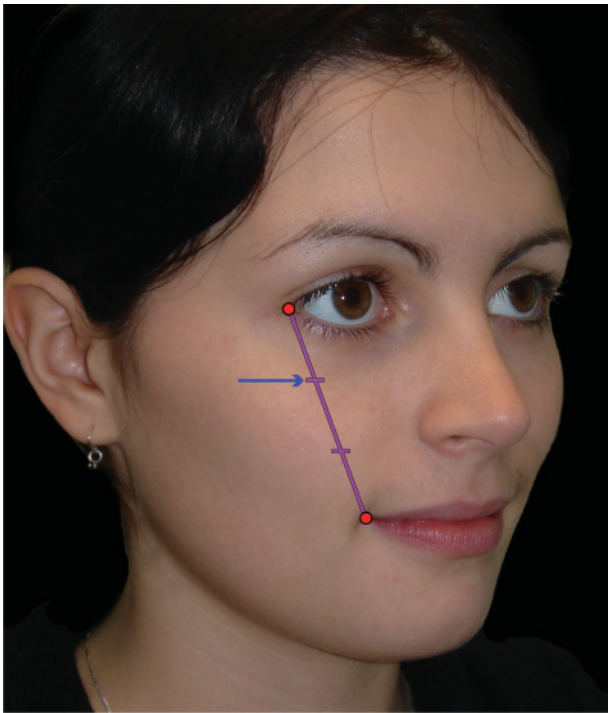


Figure 15.13 Prendergast and Schoenrock's method.

- **Prendergast and Schoenrock's method** (Figure 15.13): Looking obliquely at the face, a line is drawn from the lateral canthus to the oral commissure. One third the distance down this line, a perpendicular line will go through the most prominent point of the malar complex.⁶

Each of these methods will locate the malar prominence in a slightly different position. Terino^{7,8} suggested division of the malar and midfacial region into anatomical zones (Figure 15.14):

- Zone 1: The largest zone; comprises the main part of the malar bone and zygomatic arch. *Augmentation of this zone will increase the projection of the malar eminence.*
- Zone 2: The middle third of the zygomatic arch. *Augmentation of this area will help to broaden the bizygomatic width, which should be the widest part of the face.*
- Zone 3: The paranasal region, which is the area medial to the infraorbital foramen and lateral to the nasal bones.
- Zone 4: This is the posterior third of the zygomatic arch.
- Zone 5: The submalar zone; this is an area within the submalar triangle (described in Chapter 16).

Principles in planning the correction of malar deficiency

Malar retrusion may present clinically as flatness or even concavity of the malar region. When sagittal malar deficiency has been diagnosed, it is also necessary to evaluate the sagittal position of the maxilla and the contour of the cheek in the midfacial

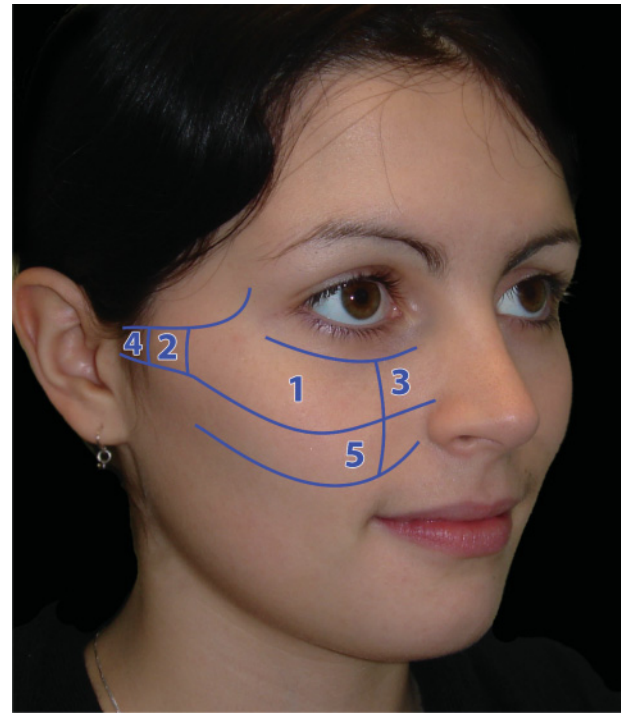


Figure 15.14 'Zonal' analysis of the malar region.

region. Solitary malar retrusion may be corrected by malar implant augmentation through an intraoral approach, via a circumvestibular incision exposing the lateral aspect of the maxilla, or by surgical advancement of the malar bones. Patients with **malar-maxillary hypoplasia**, i.e. marked midfacial deficiency, but with normal nasal projection may require the Kufner modification of the Le Fort III type advancement procedure, i.e. simultaneous advancement of the malar-maxillary complex, or alternatively a Le Fort I type maxillary advancement and separate malar augmentation.

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Chapter 16 The Maxilla and Midface

Introduction

The terms 'maxilla' and 'midface' are not synonymous. The midface, or middle region of the face, is the area between a superior plane drawn through the zygomaticofrontal sutures and an inferior plane, taken as the maxillary dental occlusal plane. These planes are not parallel, but converge posteriorly. The midface may therefore be considered a somewhat three-dimensional triangular region, with its base facing anteriorly. The midfacial region is composed of the two maxillae, the two zygomatic bones and the naso-orbito-ethmoidal complex. This **maxillary complex** shields the cranium from the masticatory forces of the mandible and *provides the dentoskeletal framework over which the midfacial soft tissues drape*. Consequently, deformities of the *composite* midface may involve these structures and their overlying soft tissues to varying extents. The comprehensive aesthetic evaluation of the midface involves the clinical evaluation of the relative size, morphology and position of these structural neighbours. This chapter deals specifically with the clinical evaluation of the maxilla (upper jaw) and its overlying soft tissue drape.

Terminology

- Pro- (prefix Greek, Latin: forward).
- Retro- (prefix Latin: backward or behind in position).
- Macro- (Greek *macros*: large or abnormally large).
- Micro- (Greek *micros*: small or abnormally small).
- Gnathos (Greek: jaw).
- -gnathia, -gnathic, -gnathism (suffix: pertaining to the maxilla and/or mandible).
- Hyper- (prefix, from Greek *huper*: over, beyond or in excess; in medicine the term denotes an abnormal excess).
- Hypo- (prefix, from Greek *hupo*: under; in medicine the term denotes a deficiency or an abnormally low level).
- Plasis: (Greek: forming or moulding), e.g. hypoplasia or hyperplasia.

Note

The etymology of the term 'maxilla' requires explanation (Latin *maxilla*: a jawbone, either upper or lower). In early anatomical texts the term 'maxilla' literally meant 'jaw', i.e. 'upper maxilla' referred to the maxilla, and the 'lower maxilla' referred to the mandible. This is the etymology of the term **bimaxillary**, which means pertaining to the maxilla and mandible, e.g. bimaxillary prognathism, bimaxillary surgery, etc. The alternative term for 'bimaxillary' is 'maxillomandibular'.

In order to successfully correct a dentofacial deformity involving the maxilla, as with any specific region of the craniofacial complex, *three systematic steps* are required:

1. Determination of the **initial position** (and quantify the size) of the maxilla in relation to the craniofacial complex.
2. Determination of the desired **final position** of the maxilla in the three planes of space and in relation to the three axes of rotation.
3. Determination of the surgical **movements** required to accomplish the desired final position.

The description of the initial position and structural relationships of the maxilla and maxillary dentition to the craniofacial complex requires an understanding of specialized vocabulary.

Terms of jaw position in the sagittal plane

Prognathic: A term used to indicate abnormal forward projection (too far forward in position) of the maxilla or mandible in the sagittal plane in relation to the rest of the craniofacial complex; the mandibular condyles are in their normal rest relationship to the glenoid fossae of the temporomandibular joints. This may be due to a relatively larger size (hyperplasia or macrognathia) and/or a more anterior position of the basal bone of the respective jaw. **Prognathism** or **prognathia** refers to the condition in which one or both jaws are prognathic.

Retrognathic: A term used to indicate lack of projection (too far back in position) of the maxilla or mandible in the sagittal plane in relation to the rest of the craniofacial complex; the mandibular condyles are in their normal rest relationship to the glenoid fossae of the temporomandibular joints. This may be due to a relatively smaller size (hypoplasia or micrognathia) and/or a more posterior position (**retroposition**) of the basal bone of the respective jaw. **Retrognathism** or **retrognathia** refers to the condition in which one or both jaws are retrognathic.

'Relative' prognathism: One jaw *appears* too far forward due to the opposing jaw being positioned too far back in relation to the craniofacial complex; e.g. relative mandibular prognathism means that the mandible may be in the correct sagittal position in relation to the craniofacial complex, but *appears* too far forward because the maxilla is too far back.

'Relative' retrognathism: One jaw *appears* too far back due to the opposing jaw being too far forward in relation to the craniofacial complex.

Protrusion: A situation in which the jaws or teeth protrude farther forward than normal; the term 'prognathism' is preferred when referring to the jaws. Protrusion also refers to the state of being thrust forward, as in masticatory movements of the mandible.

Retrusion: The state of being located posterior to the normal position.

Dentoalveolar protrusion: Anterior position (too far forward) of the maxillary or mandibular dentoalveolus relative to the supporting skeletal base and craniofacial complex, e.g. maxillary dentoalveolar protrusion refers to the excessive anterior position of the maxillary dentoalveolus relative to the maxillary skeletal base and the rest of the facial profile.

Dentoalveolar retrusion: Posterior position (too far back) of the maxillary or mandibular dentoalveolus relative to the supporting skeletal base and craniofacial complex, e.g. bimaxillary dentoalveolar retrusion refers to the excessive posterior position of the maxillary and mandibular dentoalveolar segments relative to the maxillary and mandibular skeletal bases and the rest of the facial profile.

Note

The terms 'protrusion' and 'retrusion' refer to the relative prominence of the dentoalveolar segments, *not* to the inclination of the long axes of the incisor teeth; i.e. protrusion and retrusion refer to relative sagittal position, whereas the terms 'proclination' and 'retroclination' refer to the inclination of the incisor teeth, e.g. the incisor teeth may be protrusive but of normal inclination, that is, not proclined.

Terms of maxillary position in the vertical plane

Vertical maxillary excess (VME): This term refers to excessive maxillary development in the vertical plane. VME may involve the posterior maxilla only (posterior VME), the anterior dentoalveolus only (anterior VME) or the entire maxilla (total VME). These are described in detail later in the chapter.

Vertical maxillary deficiency (VMD): This term refers to lack of maxillary development in the vertical plane.

Terms of jaw size

Macrognathia: Enlargement or elongation of the jaw; synonym: megagnathia.

Micrognathia: Abnormal smallness or reduced length of a jaw.

Hypoplasia: Underdevelopment of a tissue or organ, usually due to a deficiency in the number of cells. When used in conjunction with a jaw, this term usually refers to a general three-dimensional reduction in the size of the jaw, e.g. maxillary hypoplasia.

Hyperplasia: An increase in the number of normal cells in a tissue or organ, excluding tumour formation, whereby the bulk of the tissue or organ may be increased. When used in conjunction with a jaw, this term usually refers to a general three-dimensional increase in the size of the jaw.

Terms of maxillary bodily movement in the three planes of space

Three-dimensional bodily movement of the maxilla is termed **bodily translation**, which may occur in the:

- Sagittal plane (forward/backward).
- Vertical plane (upward/downward).
- Transverse plane (right/left).

Terms of maxillary rotation around the three axes of rotation

Maxillary rotation around the three axes of rotation is important mostly in relation to the effect on the maxillary occlusal plane (Figure 16.1):

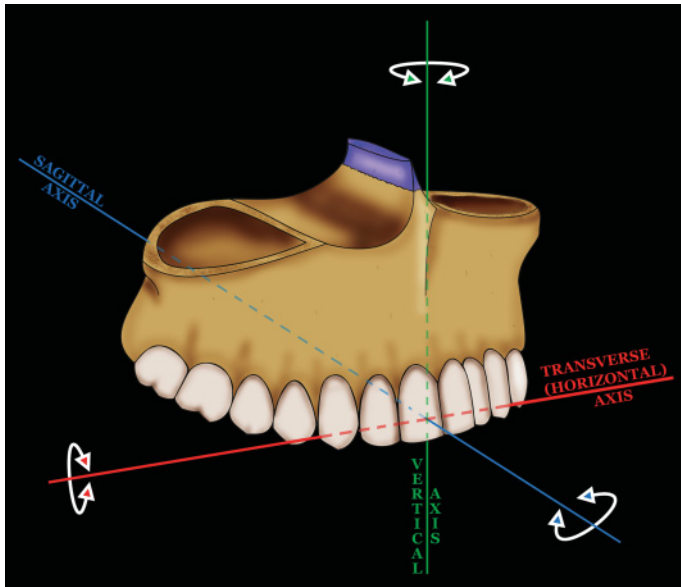


Figure 16.1 Maxillary rotation around the three axes of rotation.

- **Rotation around the vertical axis:** This is termed **maxillary arch rotation** (or **yaw**), leading to transverse movement of the dental midline.
- **Rotation around the sagittal axis:** Rotation of the maxillary occlusal plane around the sagittal axis leads to a **transverse cant** (or **roll**), i.e. the left or right posterior dentoalveolus will be at a higher or lower level in relation to the contralateral dentoalveolus.
- **Rotation around the transverse (horizontal) axis:** Rotation of the maxillary occlusal plane around the transverse axis leads to a change in **inclination** (**sagittal cant** or **pitch**), i.e. incisors will be at a higher or lower level in relation to the molars.

Anatomy

The 'maxilla' is the term used to define the upper jaw, which in fact is made up of the two maxillae, each consisting of a **body** and four **processes**. The body is roughly pyramidal in shape (Figure 16.2). Its interior is hollowed out by the **maxillary paranasal air sinus**, alternatively termed the **maxillary antrum**. The upper (orbital) surface of the body occupies the floor of the orbit; the posterior surface provides the anterior wall of the infratemporal fossa, the medial surface is a major structural component in the wall of the nasal cavity and the *anterior surface forms the curved external surface of the upper jaw*. Above the incisor teeth the anterior surface has a shallow depression termed the **incisive fossa**. Lateral to this is a ridge termed the **canine eminence**, formed by the root of the canine tooth, which separates the incisive fossa from the further lateral and deeper **canine fossa**. Above the canine fossa is the **infraorbital foramen**. The anterior surface ends medially at the pear-shaped piriform (anterior nasal) aperture, inferior to which the maxillae form a median projection, the **anterior nasal spine**.

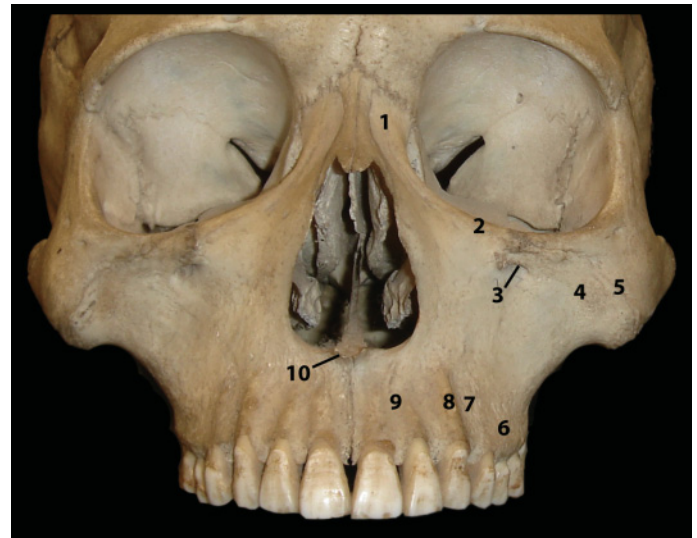


Figure 16.2 Maxilla and midface (frontal view):

- 1 Frontal process
- 2 Inferior orbital margin
- 3 Infraorbital foramen
- 4 Zygomatic process
- 5 Zygomaticomaxillary suture
- 6 Alveolar process
- 7 Canine fossa
- 8 Canine eminence
- 9 Incisive fossa
- 10 Anterior nasal spine

The four maxillary processes are (Figure 16.3):

- The **zygomatic process**: This projects laterally from the body, forming the anterior part of the zygomatic arch.
- The **frontal process**: This projects upwards to articulate with the frontal bone, and forms the lateral wall of the nose, articulating medially with the nasal bone.
- The **palatine process**: This projects medially to articulate with that of the opposite side, together forming the anterior three-quarters of the **bony palate**; the posterior one-quarter is formed by the horizontal plates of the palatine bones. The bony palate provides the roof of the oral cavity and the floor of the nasal cavity. The right and left sides of the bony palate are separated by the **median suture**. The posterior border of the bony palate has a median projection, termed the **posterior nasal spine**. The bony palate, together with its covering mucous membrane, is termed the **hard palate**. The hard palate is arched more by the downward projecting alveolar processes of the maxillae than by any upward concavity of the palatine processes.
- The **alveolar process**: This projects downwards, forming the alveoli (sockets) for the roots of the maxillary teeth. The alveolar process ends posteriorly at the **maxillary tuberosity**, a prominent rounded eminence located behind the last molar tooth.

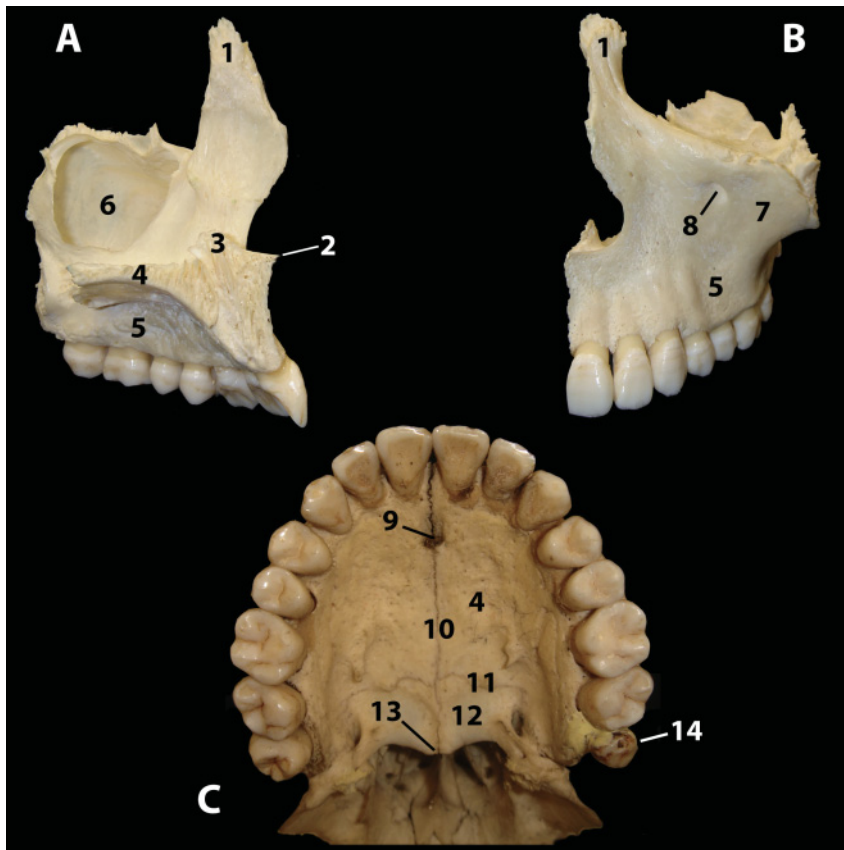


Figure 16.3 Maxilla: (A) Medial view of left maxilla; (B) frontal view of left maxilla; (C) inferior view of bony palate:

- 1 Frontal process
- 2 Anterior nasal spine
- 3 Nasal crest
- 4 Palatine process of maxilla
- 5 Alveolar process of maxilla
- 6 Maxillary hiatus leading to the maxillary sinus
- 7 Zygomatic process of maxilla
- 8 Infraorbital foramen
- 9 Incisive fossa
- 10 Median palatine suture
- 11 Transverse palatine suture
- 12 Horizontal plate of palatine bone
- 13 Posterior nasal spine
- 14 Maxillary tuberosity (with partially erupted third molar tooth)

Note

The floor of a *large* maxillary air sinus may dip into the alveolar process and lie at a lower level than the palatine process.

- Sagittal axis
- Vertical axis
- Transverse/horizontal axis.

Maxillary evaluation

Soft tissue evaluation

It is often useful to mask the lower lip and mandibular region when evaluating the midface, particularly in profile view, in order to reduce the visual influence of the relative position of these lower facial structures (Figure 16.4).

Scleral exposure: In a patient with normal midfacial morphology and in NHP there should be no sclera exposed either above or below the irides in a relaxed eyelid position and forward gaze. Increased scleral exposure above the lower eyelid and below the iris of the eye is a sign of sagittal upper midfacial deficiency due to retrusion of the inferior orbital rim (Figure 16.5).

Inferior orbital rim projection: Reduced sagittal projection of the inferior orbital rim is an important indicator of midfacial retrusion. In profile view, the most anterior part of the globe of the eye is approximately 2–3 mm anterior to the *soft tissue* inferior orbital rim, equating to 3–4 mm anterior to the *bony* inferior orbital rim. The lateral orbital rim will be approximately 12–16 mm behind the most anterior projection of the globe (Figure 16.6) (see Chapter 12, section on ‘Relationship of bony orbit and globe’).

Clinical evaluation

The patient should be examined in natural head position (NHP), with the mandible in the rest position and the facial soft tissues in repose. The clinical evaluation essentially has three parts:

- **Evaluation of the upper and lower midface:** It is important to evaluate the *soft tissue* and *skeletal components* of the **upper midface** (malar eminence, inferior orbital margin, projection of the cheek and subpupil region) and the **lower midface** (paranasal region, nasal-alar base and upper lip).
- **Evaluation of the maxillary position in the three planes of space:** It is necessary to evaluate the **maxillary position** in the:
 - Sagittal (anteroposterior) plane
 - Vertical plane
 - Transverse plane.
- **Evaluation of maxillary rotation around three axes of rotation:** It is necessary to evaluate the **rotation of the maxillary corpus and maxillary occlusal plane** around the:



Figure 16.4 Masking the lower lip and mandibular region with a piece of card when evaluating the midface, particularly in profile view, helps to reduce the visual influence of the relative position of these lower facial structures.

Cheek morphology and contour: The **soft tissue cheek** and its supporting skeletal framework form an important ‘facial aesthetic unit’ of the midfacial region. The **borders of the cheek** are (Figure 16.7):

- Superiorly: inferior orbital rim and zygomatic arch.
- Inferiorly: just above the inferior border of the mandible.
- Laterally: just anterior to the preauricular crease.
- Medially: middle and lower third of the lateral border of the nose and nasolabial fold.

The soft tissue cheek is supported by the maxilla and malar bones, the associated muscles, subcutaneous tissues, the malar fat pad and the **buccal fat pad**. The buccal fat pad is a component of the face that is essentially independent of the degree of generalized body fat. When excessive, removal of the pad may help to ‘skeletonize’ the midface, but age-related changes must be taken into account. Ptosis of the pad may occur with advancing age, increasing the inferior cheek volume lateral to the mandibular body and amplifying the appearance of jowling. Combined with the generalized atrophy of midfacial fat and descent of midfacial soft tissues that occurs with age, a resultant **submalar concavity** may occur, which may be accentuated if the buccal fat pad has been removed previously.

Midfacial soft tissue deficiencies tend to be located within an area described as the **submalar triangle** (Figure 16.8).¹ This

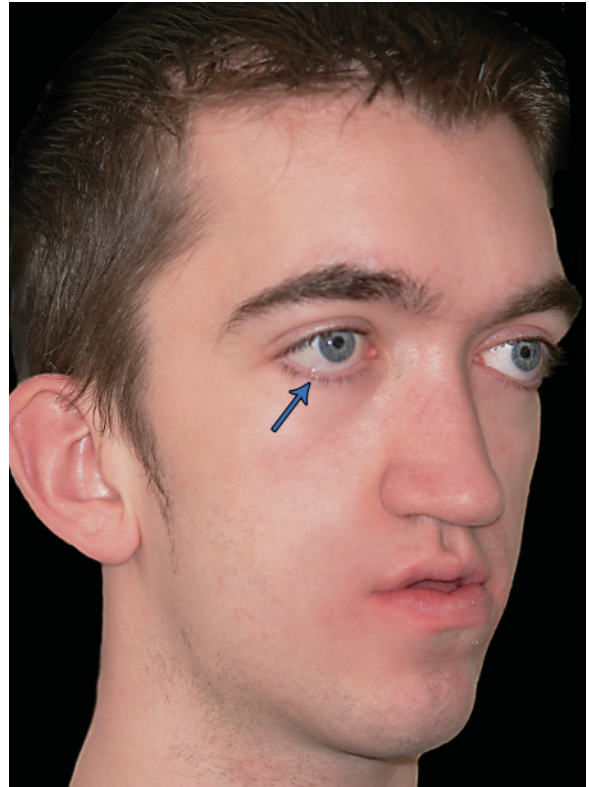


Figure 16.5 Increased scleral exposure above the lower eyelid and below the iris of the eye is a sign of sagittal upper midfacial deficiency due to retrusion of the inferior orbital rim.

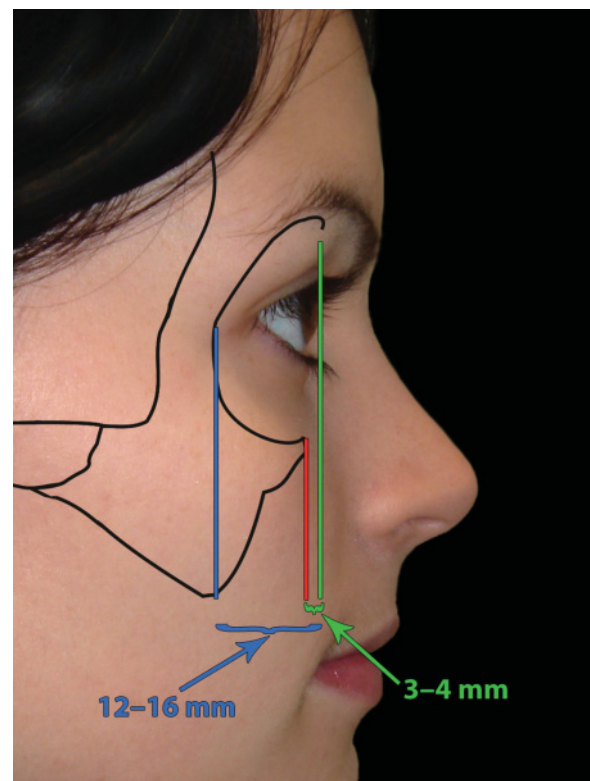


Figure 16.6 Inferior orbital rim projection in relation to the globe and lateral orbital rim.



Figure 16.7 The borders of the soft tissue cheek. (Modified, detail, *Head of a Girl*, Leonardo da Vinci, c. 1483; Biblioteca Reale, Turin).

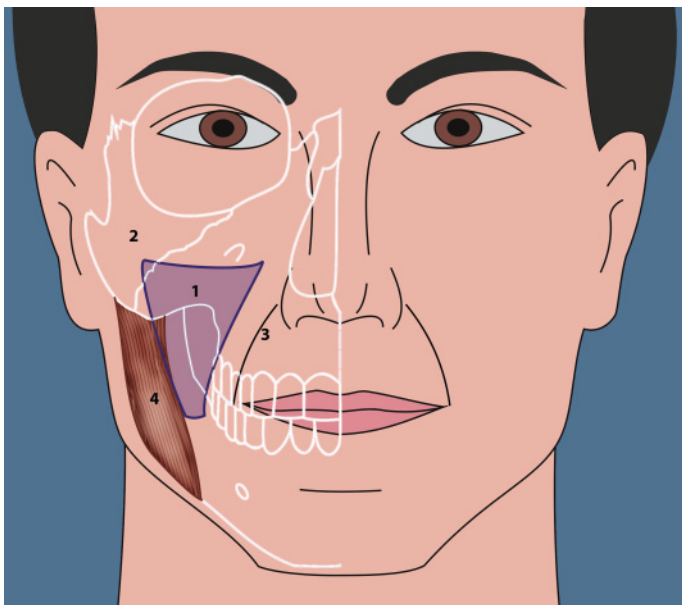


Figure 16.8 The submalar triangle (1) is bordered superiorly by the malar eminence (2), medially by the nasolabial fold (3) and laterally by the masseter muscle (4).

inverted triangular area of midfacial depression is bordered medially by the nasolabial fold, superiorly by the malar eminence and laterally by the masseter muscle. If the midfacial soft tissue descent and volume loss associated with ageing occur in a patient with underlying zygomatico-maxillary skeletal deficiency, the result will be an excessively hollow overall midfacial

appearance, with deep folds and wrinkles. In patients with malar prominence, the result will be depressions in the submalar region. Accurate diagnosis of such conditions is critical for correct treatment planning and management tends to centre on a combination of midfacial lifting, augmentation and rhytidectomy.

Midfacial curvilinear relationship: A **midfacial curvilinear contour line** may be seen, originating in the soft tissues overlying the zygomatic arch, extending anteriorly along the arch then anteromedially and subsequently inferiorly to the **subpupil region** (located in line with the pupil of the eye, midway between the inferior orbital rim and the nasal base) over the soft tissues of the cheek, down to the paranasal region (Figure 16.9). From here the line extends inferolaterally along the lateral aspect of the upper lip, ending just lateral to the oral commissure. The line should form a smooth, uninterrupted convex curve. An interruption of this line constitutes a **contour defect**, which may signify an underlying skeletal deformity, e.g. a contour defect in the paranasal region is a sign of sagittal maxillary deficiency.

Paranasal region: The paranasal region of interest is that just lateral to the nasal alae. The paranasal region ideally should be slightly convex. Sagittal maxillary deficiency often results in flattening or even concavity of this region, described as **paranasal hollowing** (Figure 16.10).

Nasal base support: The nasal base is supported by the maxilla. Therefore, flatness or concavity of the nasal base region is an indication of maxillary deficiency (Figure 16.11).

Nasal projection: In profile view, the ratio of the horizontal linear distance from nasal tip (pronasale) to subnasale and from subnasale to alar base crease is approximately 2:1 (Figure 16.12). Assuming that the nose itself is of normal size, a reduction in this ratio may indicate sagittal maxillary deficiency.

Upper lip prominence: The prominence of the upper lip is related to the sagittal position of the maxilla and maxillary dentoalveolus, albeit variable depending on the upper lip thickness. A retrusive upper lip may be a sign of sagittal maxillary deficiency, and a protrusive upper lip a sign of sagittal maxillary excess.

Upper lip inclination: The inclination of the upper lip provides an indication of the relative sagittal prominence of the maxillary dentoalveolus.

- **Upper lip inclination to nasion-perpendicular (McNamara)** (Figure 16.13): The inclination of the upper lip may be evaluated using a line tangent to the upper lip (labrale superius to subnasale) extended to intersect the nasion-perpendicular. The angle should be:²

- Male: $8^\circ \pm 8^\circ$
- Female: $14^\circ \pm 8^\circ$.

- **Nasolabial angle (lower component)** (Figure 16.14): To assess the inclination of the upper lip, the nasolabial angle may be separated into upper and lower component parts using a true horizontal line through subnasale. This will allow the columella tangent-true horizontal plane (upper component) and the upper lip tangent-true horizontal plane (lower component) angles to be assessed separately, as they

Figure 16.9 The midfacial curvilinear contour line should form a smooth, uninterrupted convex curve. In this patient with sagittal maxillary deficiency, there is a concave contour defect of this line (yellow) in the subpupil and paranasal regions, which should follow the broken green convex contour on the figure. (A and B) Frontal view; (D and E) profile view. (C and F) Following maxillary advancement, the subpupil and paranasal regions are convex.



Figure 16.10 Paranasal hollowing. (A) Paranasal region is concave as a result of sagittal maxillary deficiency, described as paranasal hollowing. (B) Maxillary advancement resulting in convexity of the paranasal region.



vary independently. Average values for upper lip tangent to true horizontal plane (lower component) are:

- 85°³
- 88–92° (indirectly calculated from original data provided by Farkas⁴).

Upper lip support: The support for the upper lip is provided by the anterior maxillary dentoalveolus, and also depends to a great

extent on the upper lip thickness and the amount of space in the upper labial sulcus between the inner surface of the upper lip and the anterior surface of the maxillary dentoalveolus.

The maxillary canine root is the longest of any tooth. The canine eminence is a bulge on the alveolar bone overlying the roots of the canine teeth, separating the incisive fossa anteriorly from the deeper canine fossa posteriorly (Figure 16.2). The canine eminence provides a degree of support to the upper lip,



Figure 16.11 Nasal base support: Sagittal maxillary deficiency may result in flatness or concavity of the nasal base region.

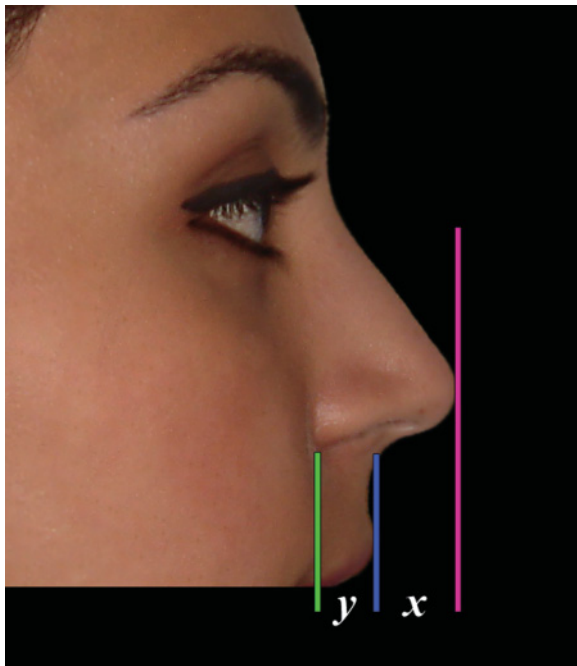


Figure 16.12 The ratio of the horizontal linear distance from nasal tip (pronasale) to subnasale (x) and from subnasale to alar base crease (y) is approximately 2:1; if the nose itself is of normal size, a reduction in this ratio may indicate sagittal maxillary deficiency.

though this depends on the thickness of the upper lip. Therefore, in patients with relatively thin lips, extraction of the maxillary canine is best avoided.

Note

A useful chairside technique in patients possibly requiring maxillary advancement is to take a wet cottonwool roll, squeeze it to make it approximately 5–6 mm thick, then place it under the upper lip and evaluate the change in upper lip prominence in profile view.

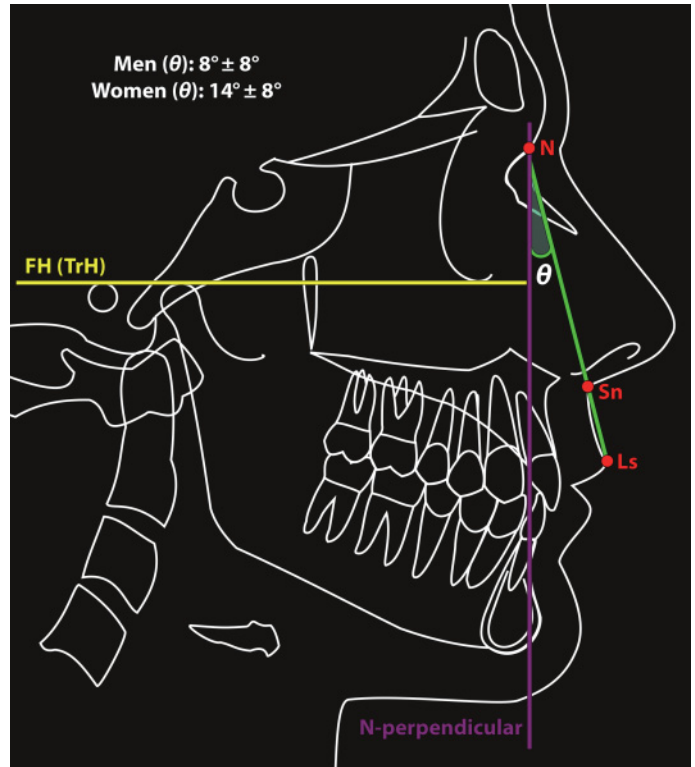


Figure 16.13 Upper lip inclination may be evaluated using a line tangent to the upper lip (labrale superius to subnasale) extended to intersect the N-perpendicular.

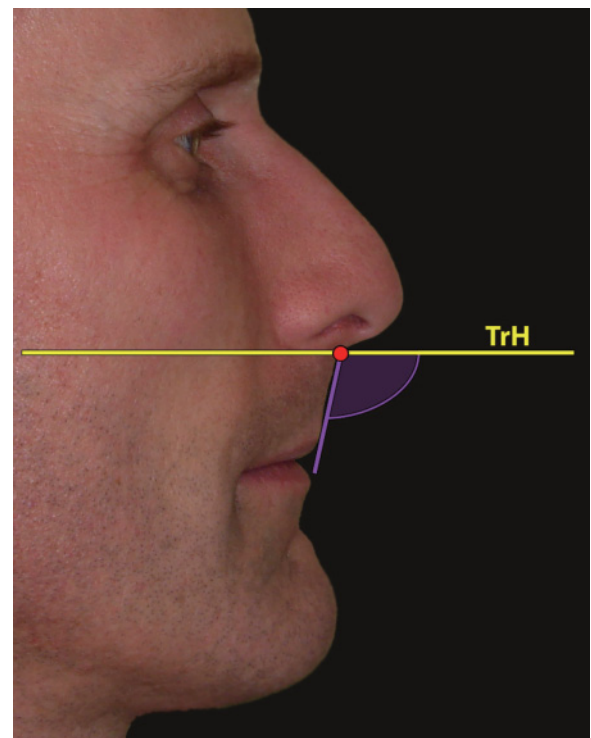


Figure 16.14 Nasolabial angle (lower component): the inclination of the upper lip may be evaluated in relation to a true horizontal plane (TrH) through subnasale. In this case, the inclination of the nasal columella is normal, but the upper lip is posteriorly inclined.

True vertical plane through glabella: With the patient in NHP, a true vertical plane may be constructed through soft tissue glabella. Subnasale should be on or just ahead of this plane. Depending on the morphology of the glabellar-nasal radix region, soft tissue nasion or a point between nasion and glabella may be used from which to drop the true vertical (see Figure 6.14).

Note

The indicators of midface retrusion, which are well correlated with maxillary retrusion, are:

- Increased scleral exposure below the irides.
- Inferior orbital rim flatness or concavity.
- Reduced projection, flatness or concavity of the malar eminence.
- Flatness or concavity of the subpupil region.
- Flatness or concavity of the paranasal region.
- Flatness or concavity of the alar bases.
- An *apparent* increase in nasal projection.

Additional features of maxillary hypoplasia are:

- Reduced upper lip support and a retrusive upper lip, particularly if the vermillion is more retrusive than subnasale.
- Retropositioned maxillary incisors.

Dentoskeletal evaluation

The sagittal position of the midface and maxilla may be evaluated relative to a number of craniofacial structures.

Inferior orbital rim projection (S-N-Or angle) (Figure 16.15): This angular cephalometric measurement is formed between the sella-nasion (SN) plane and the nasion-orbitale (N-Or) plane.⁵ The angle will be reduced in sagittal deficiency of the upper midface, assuming a normal cranial base inclination. Average value: $54^\circ \pm 3^\circ$.

Maxilla to anterior cranial base (SNA angle) (see Figure 7.17): The SNA angle relates the sagittal position of the maxillary apical base (A-point) to the anterior cranial base (SN). The SNA angle gives an indication of the sagittal position of the maxilla relative to the anterior cranial base. Normal value: $82^\circ \pm 3^\circ$.

Maxilla to nasion perpendicular (McNamara) (see Figure 7.14): The sagittal position of the maxilla may be determined by measuring the horizontal linear distance to the nasion perpendicular, a vertical line perpendicular to the true horizontal, dropped from nasion.²

- Maxillary point A should be on or slightly ahead of nasion perpendicular (0 to +1 mm).

Maxillary incisor sagittal position (see Figure 7.37): The sagittal position of the maxillary incisors in relation to the maxillary skeletal base and the facial profile is one of the cornerstones of treatment planning in orthognathic surgery. A vertical line is drawn through maxillary A-point, parallel to the N-perpendicular, and perpendicular to the Frankfort horizontal (or ideally true horizontal) plane. The McNamara analysis guideline is:²

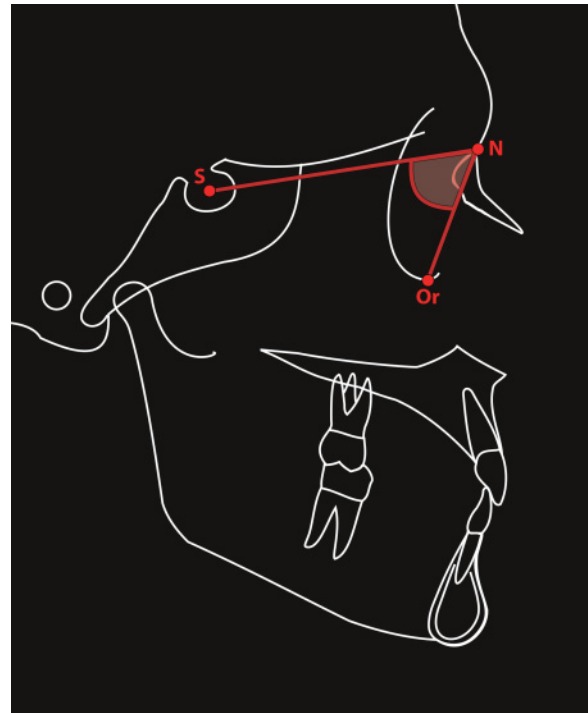


Figure 16.15 Inferior orbital rim projection evaluation with the S-N-Or angle.

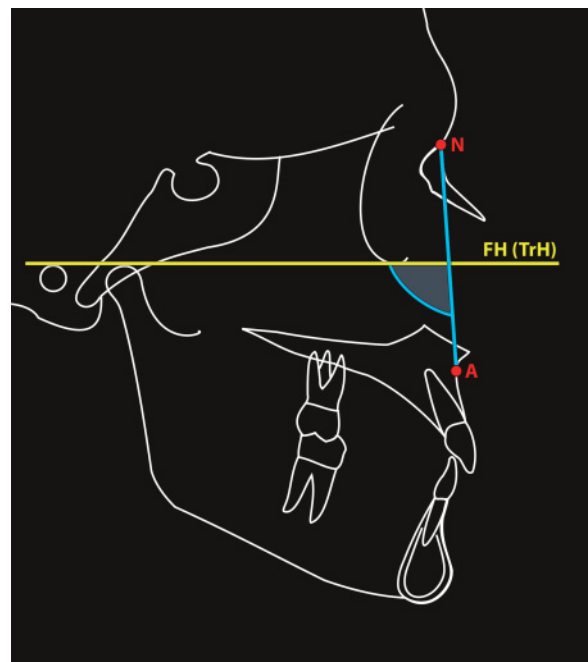


Figure 16.16 The sagittal position of the maxillary apical base may be evaluated relative to the Frankfort Horizontal (FH; or ideally true horizontal, TrH) plane.

- The labial (facial) surface of the maxillary incisor should be 4–6 mm ahead of the line.

Maxilla to Frankfort Horizontal plane (NA to FH angle) (Figure 16.16): The sagittal position of the maxillary apical base



Figure 16.17 Maxillary incisor exposure in relation to upper lip. (A) In repose – in the presence of normal upper lip height, this provides an important indication of the vertical position of the anterior maxilla. (B) Posed smile. (C) Spontaneous smile.

may be evaluated relative to the Frankfort Horizontal (or ideally true horizontal) plane:

- Male and female (UK):⁶ $90^\circ \pm 3^\circ$.
- Male (USA):⁷ $85^\circ \pm 4^\circ$.
- Female (USA):⁷ $88^\circ \pm 4^\circ$.

Maxilla to mandible (ANB angle) (see Figure 7.24): The ANB angle provides an indication of the sagittal relationship of the maxilla to the mandible by evaluating the sagittal discrepancy between the maxillary and mandibular apical bases. The skeletal pattern may be described as:

- Class I: the ANB angle is in the normal range $2\text{--}4^\circ$.
- Class II: if ANB angle greater than 4° .
- Class III: if ANB angle less than 2° .

Midfacial to mandibular unit lengths (see Figure 7.31): The midfacial unit length provides an indication of the sagittal position of the maxilla. The difference between the midfacial (condylion-point A) and mandibular (condylion-gnathion) unit lengths provides an indication of the **size discrepancy** between the jaws.² There is a linear relationship between the midfacial and mandibular unit lengths: each value for midfacial unit length corresponds to a value for mandibular unit length, within a given range (see Figure 7.32).²

Maxillary length (PNS-ANS): The absolute length of the maxilla may be measured from posterior nasal spine (PNS) to the anterior nasal spine (ANS). The normal values in adults are:

- Male (UK):⁶ 54 ± 3 mm.
- Female (UK):⁶ 50 ± 2 mm.
- Male (USA):⁷ 62 ± 4 mm.
- Female (USA):⁷ 57 ± 4 mm.

The value for PNS to maxillary point A should be approximately 5 mm less than PNS-ANS.

Vertical maxillary evaluation

Vertical anterior face height ratio (see Figure 7.45): The ratio of midfacial to lower anterior face height must be evaluated both clinically (soft tissue) and on the lateral cephalometric radiograph (hard tissue).

- **Clinical/soft tissue:** Midface height is measured from glabella to subnasale. Lower face height is measured from

subnasale to menton. The proportional relationship of MAFH:LAFH is approximately 50:50. This proportional relationship is more important than any absolute measurements.

- **Cephalometric/skeletal:** The proportional relationship of skeletal midface height (nasion to ANS) to lower face height (ANS to menton) should be 45:55%.

Maxillary incisor exposure in relation to upper lip: In the presence of *normal upper lip height*, the maxillary incisor exposure in relation to the upper lip provides an important indication of the vertical position of the maxilla. The patient must be evaluated with the mandible in the rest position and the lips in repose. The normal relationships are as follows (Figure 16.17):

- Normal maxillary incisor exposure at rest: 2–5 mm.
- Maxillary incisor exposure on posed smile: full incisor crown exposure.
- Maxillary incisor exposure on spontaneous smile: full incisor crown and 1–2 mm gingival exposure.

Excessive maxillary incisor exposure at rest may be due to:

- Total VME.
- Overeruption of the maxillary incisors (anterior dentoalveolar VME).

If the maxillary incisor region is overerupted, excessive gingival exposure will only be evident anteriorly on smiling. Total VME results in the entire maxillary dentition being excessively inferiorly positioned. On smiling, excessive gingival exposure will be evident both anteriorly and posteriorly.

Note

In some patients there is posterior VME, but without increased incisor exposure in relation to the upper lip. This is because anterior vertical dentoalveolar development has been impeded by a forward resting tongue position.

Orientation of the sagittal maxillary occlusal plane around the transverse/horizontal axis: In the normal situation the maxillary plane (ANS-PNS) converges with the other facial planes near the occiput (Sassouni analysis) (see Figure 7.44A).⁸ Clinically, the sagittal maxillary occlusal plane may be approximately parallel to the alar-tragal line (Camper's plane). The

inclination of the maxillary plane in relation to the anterior cranial base (SN plane) (see Table 7.10) is:

- Male (UK):⁶ $6^\circ \pm 2^\circ$.
- Female (UK):⁶ $7^\circ \pm 3^\circ$.
- Male (USA):⁷ $7^\circ \pm 3^\circ$.
- Female (USA):⁷ $8^\circ \pm 2^\circ$.

Skeletal deformities resulting in *rotation of the maxilla around the transverse axis* may result in a change in inclination (sagittal cant) of the maxillary occlusal plane. Patients with increased face height and posterior growth rotation of the mandible often have VME. If the posterior VME is greater than the anterior VME, a resultant sagittal occlusal plane cant will be evident.

Note

It is very important to evaluate the sagittal maxillary occlusal plane by analysing four parameters (Figure 16.18):

- **Inclination of the maxillary plane (ANS-PNS):** This will be evident on observation of the lateral cephalometric radiograph and will demonstrate sagittal rotation of the maxilla itself. It is also useful to compare the anterior midface height (N-ANS) to the posterior midface height (S-PNS):
 - Anterior midface height:
 - Male: UK:⁶ 54 ± 2 mm; USA:⁷ 60 ± 4 mm
 - Female: UK:⁶ 51 ± 2 mm; USA:⁷ 56 ± 2 mm.
 - Posterior midface height:
 - Male: UK:⁶ 50 ± 2 mm; USA:⁷ 56 ± 4 mm
 - Female: UK:⁶ 45 ± 2 mm; USA:⁷ 51 ± 3 mm.
- **Sagittal maxillary occlusal curve:** The sagittal maxillary occlusal curve is equivalent to the curve of Spee in the mandibular arch. In the normal situation this will be almost flat; any form of increased or reverse curve is a sign of an underlying dentoskeletal discrepancy.
- **Anterior vertical maxillary dentoalveolar position:** This is best evaluated by the maxillary incisor exposure in relation to the upper lip (albeit depending on upper lip height) and the linear measurement of vertical anterior dentoalveolar development:
 - Linear distance of maxillary incisor edge perpendicular to maxillary plane:
 - Male (UK):⁶ 28 ± 3 mm (USA:⁷ 33 ± 3 mm)
 - Female (UK):⁶ 27 ± 3 mm (USA:⁷ 30 ± 3 mm).
- **Posterior vertical maxillary dentoalveolar position:** This may be evaluated by the linear measurement of vertical posterior dentoalveolar development:
 - Linear distance of maxillary molar mesiobuccal cusp tip perpendicular to maxillary plane:
 - Male (UK):⁶ 27 ± 3 mm (USA:⁷ 28 ± 3 mm)
 - Female (UK):⁶ 24 ± 3 mm (USA:⁷ 25 ± 2 mm).

These values help in deciding where the problem lies and thereby what may need to be done, i.e. does the maxilla or maxillary dentoalveolus need to be repositioned up or down anteriorly and/or posteriorly.

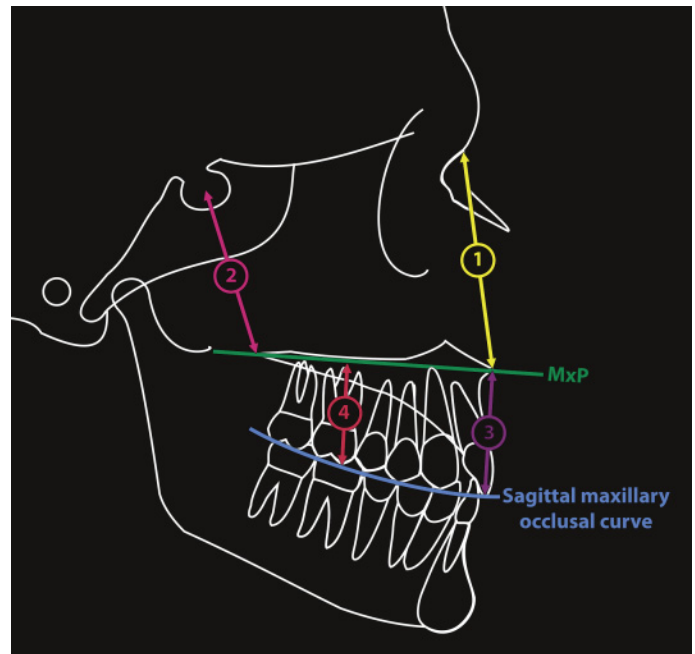


Figure 16.18 Sagittal maxillary occlusal plane evaluation. 1: Anterior midface height; 2: Posterior midface height; 3: Anterior vertical maxillary dentoalveolar position; 4: Posterior vertical maxillary dentoalveolar position; MxP, maxillary plane. The sagittal maxillary occlusal curve is the equivalent of the mandibular occlusal curve of Spee.

Transverse maxillary evaluation

Maxillary width and dental arch width

Dental study casts (study models) are extremely valuable in the evaluation of transverse dental arch width discrepancies. An understanding of normal dental-occlusal relationships is required in order for the clinician to detect the presence of any occlusal discrepancies (see Chapter 22). If a transverse occlusal discrepancy is identified, the next step is to determine whether the aetiology is of dental, skeletal or combined dentoskeletal origin.

The main dental arch discrepancy to observe is a **posterior crossbite**, which exists when the buccal cusps of the posterior maxillary teeth occlude palatal, rather than buccal, to the mandibular teeth. This may be caused by:

- Maxillary arch too narrow:
 - Skeletal origin: Reduced maxillary skeletal width
 - Dental origin: Palatally inclined posterior teeth.
- Mandibular arch too wide.
- Combination of the above.

Comparison of a patient's maxillary and mandibular dental arch width measurements with normal arch width standard values may be useful (Table 16.1).

An idea of the outer skeletal width of the maxilla may be gleaned from the dental study casts if the impressions have been

Table 16.1 Dental arch width measurements (age 18)

Tooth	Maxillary arch (mm)		Mandibular arch (mm)	
	Male	Female	Male	Female
Inter canine width	32	31	25	23
Inter first premolar width	37	35	33	31
Inter second premolar width	41	40	38	36
Inter first molar width	47	45	43	42
Inter second molar width	52	49	49	47

Note: Distances are measured between centres of the teeth; SD ~2mm.
Data from Moyers et al.⁹

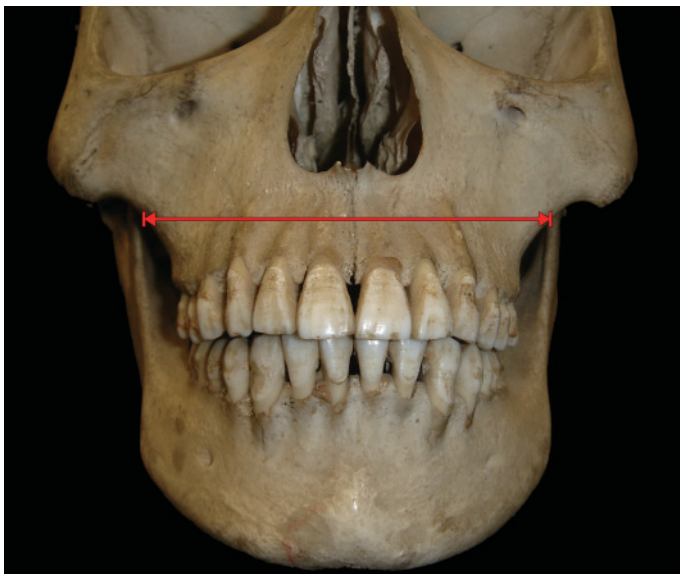


Figure 16.19 Maxillary skeletal width may be measured between left and right maxillary landmarks.

well extended in the buccal sulcus. This measurement may also be made on a posteroanterior cephalometric radiograph or a three-dimensional reconstruction. Normal maxillary basal bone (skeletal) width (measured from left to right maxillary) (Figure 16.19):

- Male and female:¹⁰ 60–65 mm.

The height and width of the palatal vault and the bucco-palatal inclination of the posterior dentition may be observed on the maxillary dental cast:

- **Normal transverse dental arch relationship** (Figure 16.20A): There is normal bucco-palatal inclination of the posterior dentition and no posterior crossbites. The width of

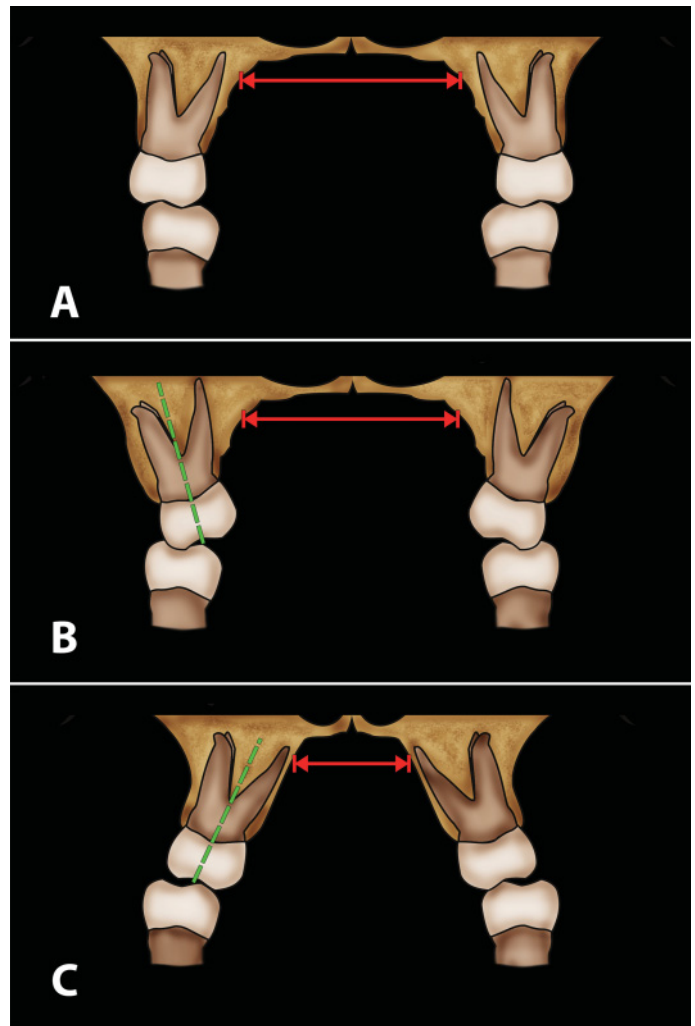


Figure 16.20 (A) Normal palatal width and normal posterior occlusal relationship in the transverse plane. (B) Bilateral posterior crossbite of dental origin – palatal vault width is normal but the dentoalveolar processes are inclined palatally. (C) Bilateral posterior crossbite of skeletal origin – the palatal vault is narrow and the dentoalveolar processes are inclined buccally.

the palatal vault is normal and the relative width of the maxillary and mandibular skeletal bases is normal.

- **Dental crossbite** (Figure 16.20B): If the posterior crossbite is dental in origin, the width of the palatal vault may be normal but the dentoalveolar processes are inclined palatally (inward).

Note

Management of a dental posterior crossbite may be undertaken by orthodontic expansion.

- **Skeletal crossbite** (Figure 16.20C): If the posterior crossbite is skeletal in origin, the palatal vault is narrow and the dentoalveolar processes are inclined buccally (outward).

Note

Management of transverse skeletal maxillary deficiency in children may be undertaken by rapid maxillary expansion (RME), a method of opening the midpalatal suture in order to increase the width of the bony palate, carried out before fusion of the suture. In adults, if the magnitude of the transverse discrepancy is greater than 5 mm and the posterior maxillary dentition already exhibits dentoalveolar compensation (is buccally inclined), a combined orthodontic-surgical approach is required to expand the maxilla.

Note

As the aetiology of maxillary dental midline deviation is almost always dental in origin, its correction should be by orthodontic tooth movement. It is sometimes possible to accept *small* midline deviations (up to 2 mm) as it has been demonstrated that a few millimetres of dental midline deviation is acceptable if the mesiodistal angulation of the maxillary incisors is correct.¹¹ Surgical correction of maxillary midline deviation by *rotation of the maxilla around the vertical axis* is only possible for a midline deviation of up to 2 mm. Any greater rotation of the maxilla would potentially result in posterior occlusal disturbances.

Maxillary dental midline

Evaluation of the maxillary dental midline in relation to the facial midline is undertaken clinically. Marking the midpoint of the philtrum and Cupid's bow of the upper lip allows the clinician to determine the extent of deviation of the maxillary dental midline from the facial midline.

The aetiology of maxillary midline deviations may be skeletal or dental:

- **Skeletal origin:** This would require the maxilla to be bodily rotated around the vertical axis. This is exceptionally rare.
- **Dental origin:** Maxillary dental midline deviations are almost always dental in origin. They may be due to crowding of the maxillary arch, early unilateral loss of a deciduous canine tooth or permanent first premolar tooth, or unilateral ankylosis of a maxillary deciduous second molar resulting in tension in the transseptal fibres.

Orientation of the transverse occlusal plane

A transverse cant of the maxillary occlusal plane may be skeletal or dentoalveolar in origin (Figure 16.21). The clinical result is *rotation of the maxillary occlusal plane around the sagittal axis*.

- **Dentoalveolar origin** (Figure 16.21A): A transverse cant of the maxillary occlusal plane is often secondary to mandibular asymmetry, particularly hemimandibular hyperplasia resulting in unilateral increase in vertical ramus height. As the mandibular dentition moves downward on the affected side, there may be compensatory overeruption of the maxillary dentoalveolus leading to a transverse cant of the maxillary occlusal plane. Therefore, the aetiology of the transverse maxillary occlusal plane cant is dental overeruption, secondary to a mandibular skeletal asymmetry. Clinical evaluation may be undertaken by asking the patient to hold a Fox's guide plane against the maxillary dental arch; this will determine a cant in the entire transverse maxillary occlusal plane (see

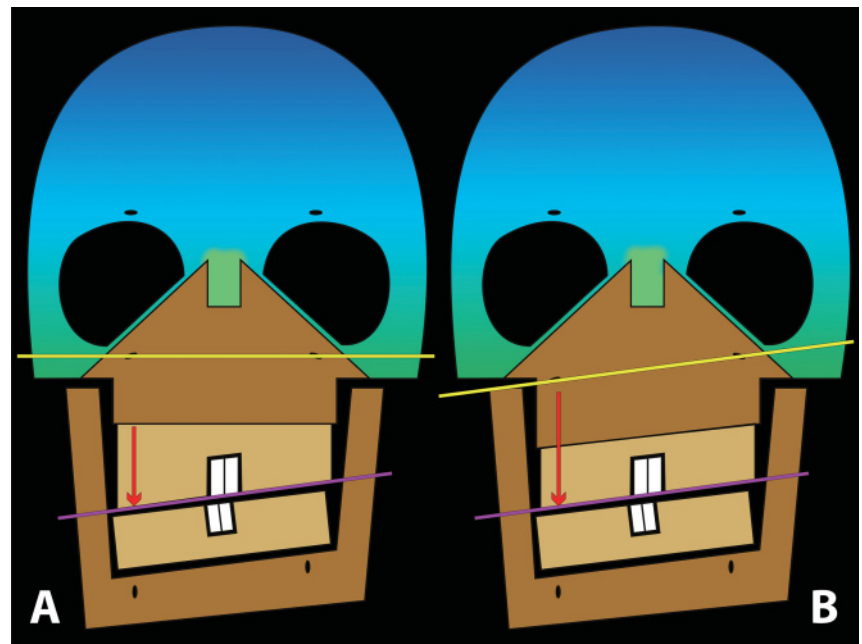


Figure 16.21 Schematic representation of the aetiology of transverse maxillary occlusal plane cant. (A) Dentoalveolar origin – compensatory overeruption of the maxillary dentoalveolus, often secondary to mandibular asymmetry, leads to a transverse cant of the maxillary occlusal plane. (B) Skeletal origin – rotation of the entire maxilla around the sagittal axis.



Figure 16.22 Maxillary hypoplasia in a patient with previously operated bilateral cleft lip and palate. Submental length and mandibular size and position are normal – the Class III skeletal relationship is due to maxillary deficiency.

Figure 10.9). It is then necessary to evaluate separately for a transverse occlusal plane cant in the incisor, canine and molar regions using a wooden tongue spatula or dental mirror handle. With the patient in NHP comparison may be made to the true horizontal plane. It is also possible to compare the orientation of the transverse occlusal plane with the **interpupillary plane**, in the absence of **vertical orbital dystopia** (orbital cavities do not lie on the same horizontal plane, i.e. one eye is higher than the other). Radiographic analysis will reveal normal transverse inclination of the inter-infraorbital foramen plane and the inter-maxillare plane. The transverse cant will be limited to the transverse occlusal plane.

- **Skeletal origin** (Figure 16.21B): If the aetiology of a transverse occlusal plane cant is skeletal it will result in *rotation of the entire maxilla around the sagittal axis*. Analysis of a postero-anterior cephalometric radiograph and a three-dimensional reconstruction will reveal a transverse cant of the inter-infraorbital foramen plane and the inter-maxillare plane, as well as the transverse occlusal plane (see Figure 10.36).

Note

Management of a transverse maxillary occlusal plane cant will involve unilateral impaction of the maxilla or unilateral inferior repositioning of the maxilla or simultaneous unilateral impaction and contralateral inferior repositioning, depending on which side is at fault. The decision to elevate or inferiorly reposition each side of the maxilla is *made clinically*, and depends to a great extent on the degree of vertical exposure of the maxillary incisors and canines in relation to the upper lip and also the lower anterior face height.

Maxillary deficiency

Maxillary deficiency is frequently three-dimensional, i.e. the maxilla is positioned too far posteriorly and superiorly, and is too narrow. The term **maxillary hypoplasia** may be used in such cases, referring to an underdeveloped, small maxilla. Such three-dimensional maxillary hypoplasia is evident in many patients

with operated cleft lip and palate, due to obstruction of maxillary development from surgical scar tissue (Figure 16.22).

The clinical features of maxillary deficiency depend on the extent and vertical level of the deficiency. Deficiency may be limited to the maxilla and lower midface, or also involve the upper midface. If there is higher maxillary and upper midface deficiency, there may be flatness of the malar region, infraorbital rims, subpupil-mid cheek region and paranasal region.

Sagittal maxillary deficiency

Sagittal midfacial and maxillary deficiency may present as:

- Retrusive appearance of upper lip.
- Mandible that may be normal in size, but *appears* prognathic due to maxillary retrognathia;
- With concomitant VMD – leading to upward and forward mandibular rotation and therefore increased chin prominence; also such overclosure makes the lips squeeze together and curl outwards.
- Facial contour angle (G-Sn-Pog' – angle of facial soft tissue convexity; norm: $12^\circ \pm 4^\circ$) is reduced or even negative, leading to a concave midfacial appearance.
- Increased nasolabial angle (lower component), due to posterior inclination of the upper lip. However, the upper component may even be negative, as the nasal tip is often hanging.
- Apparent nasal prominence, due to retrusive upper lip and lower midface, and paranasal hollowing.
- Reduced or non-existent maxillary incisor exposure at rest and, in more severe cases, even on smiling. In concomitant VMD, the maxillary incisor tips tend to be at a vertical level superior to the upper lip.
- Obvious retrusion of the anterior wall of the maxillary sinus resulting from retroposition or hypoplasia of the maxilla (Figure 16.23) – the anterior wall of the maxillary sinus may be inferoposteriorly inclined, with an increased distance to the anterior nasal spine.
- The following dental-occlusal relationships (Figure 16.24):

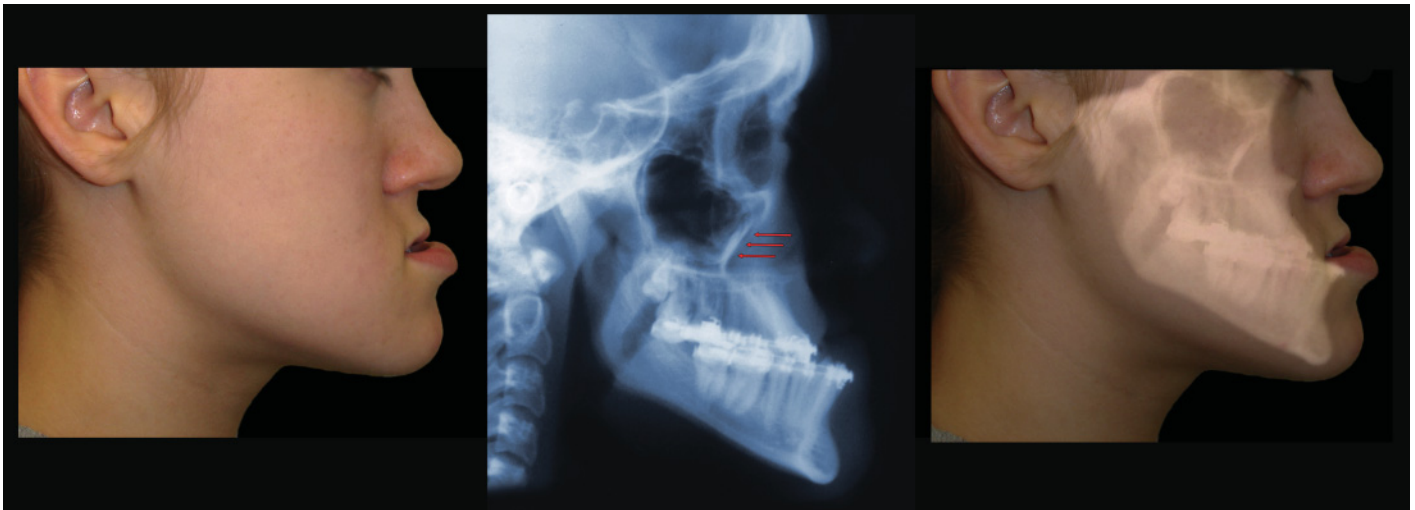


Figure 16.23 Sagittal maxillary deficiency (combined with mandibular excess) with retrusion of the anterior wall of the maxillary sinus, which is inferoposteriorly inclined, with an increased distance to the anterior nasal spine.



Figure 16.24 Sagittal maxillary deficiency resulting in a reverse incisor overjet, tendency to posterior crossbite and compensatory maxillary incisor proclination.

- Reverse incisor overjet
- Tendency to posterior crossbite
- Dentoalveolar compensation for the underlying skeletal pattern – proclination of maxillary incisors (with or without retroclination of the mandibular incisors depending on the presence of concomitant mandibular excess).
- Chin-neck (submental) length is normal, compared with patients with mandibular excess, in whom this distance is increased (Figure 16.25).

Vertical maxillary deficiency

Lack of maxillary development in the vertical plane is termed **vertical maxillary deficiency (VMD)**. Patients with VMD tend to exhibit a *markedly reduced lower anterior facial height*, sometimes termed a **short face deformity** (Figure 16.26). The presenting features are:

- Reduced total anterior face height (TAFH), mainly due to a reduced lower anterior face height (LAFH); the face is square-shaped in frontal view.
- Lack of inferior maxillary skeletal development (VMD): There is very little bone between the nasal floor and the root apices of the maxillary teeth; in fact, the maxillary root apices may extend into the maxillary sinuses.
- Upper lip–incisor relationship:
 - Reduced exposure of the maxillary incisors in relation to the upper lip in repose. With the mandible in the rest position and the lips in repose, the incisal edges of the maxillary incisors are positioned above the inferior margin of the upper lip.
 - There is reduced or non-existent tooth show on smiling, giving an aged appearance to the smile.
- Anterior (upward and forward) mandibular rotation – this will affect the apparent sagittal prominence of the chin, which is often pronounced. The mentolabial fold is relatively deep; the mentolabial angle is reduced.
- Reduced mandibular plane angle; hence the terms **low angle** facial type or **hypodivergent** face.
- Bigonial width is increased, the **gonial angles** are reduced and there may be masseteric hypertrophy, giving a square appearance to the lower face.
- Lip prominence – lips are effectively squeezed together due to the reduced LAFH.

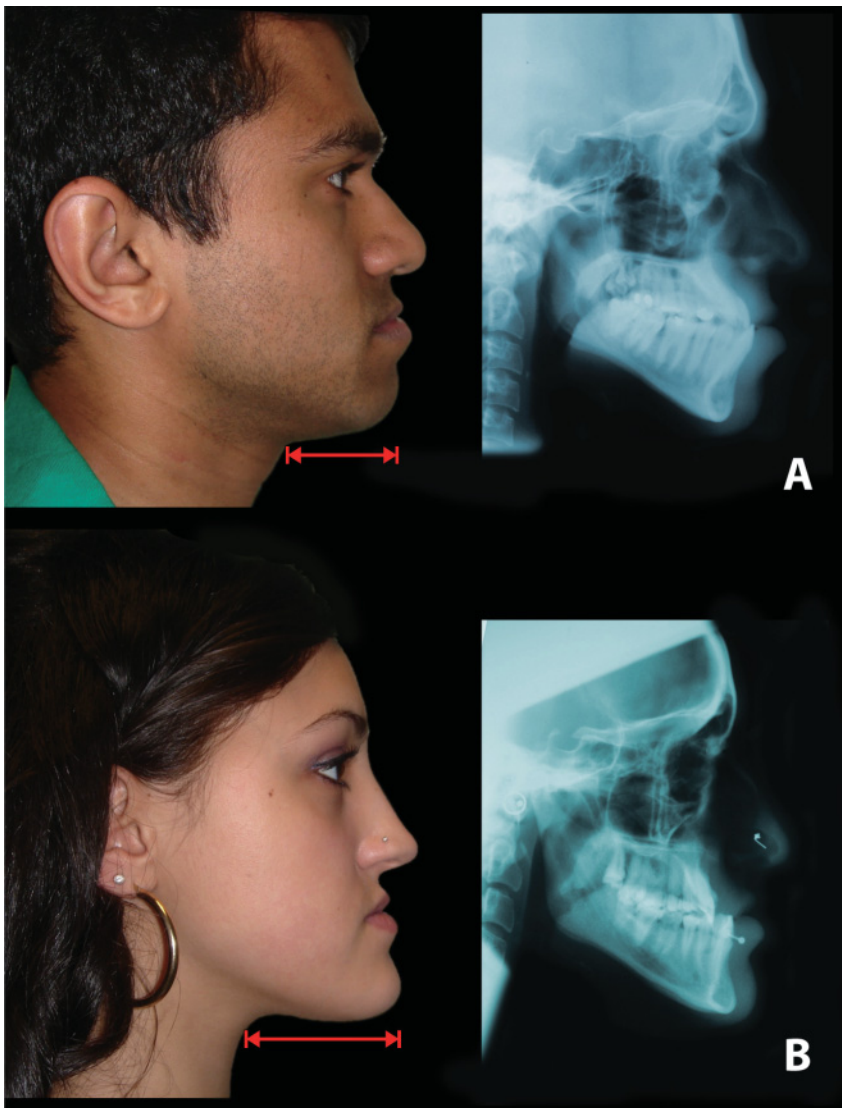


Figure 16.25 (A) Class III skeletal pattern mainly due to sagittal maxillary deficiency, with chin-neck (submental) length within normal limits. (B) Class III skeletal pattern due to maxillary deficiency and mandibular excess, with increased chin-neck length.

- Mouth width appears increased; the oral commissures turn downward, giving a frown-like appearance.
- Nose – tends to have increased alar base width.
- Palatal vault – tends to be flat and broad. This may be due to a high tongue position due to the reduced LAFH. Therefore, there is a tendency to bilateral scissors bite.
- Dental occlusion:
 - Incisor overbite is increased. When the primary aetiological factor in the presence of a deep bite is the reduced lower anterior face height, it is termed a **skeletal deep bite** (Sassouni analysis).
 - Freeway space is increased to approximately 10 mm. The freeway space, or interocclusal separation, is the distance between the occlusal surfaces of the maxillary and mandibular teeth when the mandible is in the rest position.

Transverse maxillary deficiency

The diagnosis and correction of transverse maxillary deficiency is important in terms of smile aesthetics, as a narrow maxillary dentoalveolus leads to a narrow and unattractive smile, and in terms of occlusal function and stability. Diagnosis of transverse dental arch discrepancies is necessary to determine the extent of maxillary/maxillary dental arch expansion (and/or mandibular dental arch contraction) that may be required in order to have well-coordinated arches following surgical repositioning of the jaws.

Relative versus absolute maxillary transverse deficiency

The clinician must bear in mind that advancement of the maxilla will bring a wider part of the maxilla forward over a narrower part of the mandible. Simulated correction of sagittal skeletal

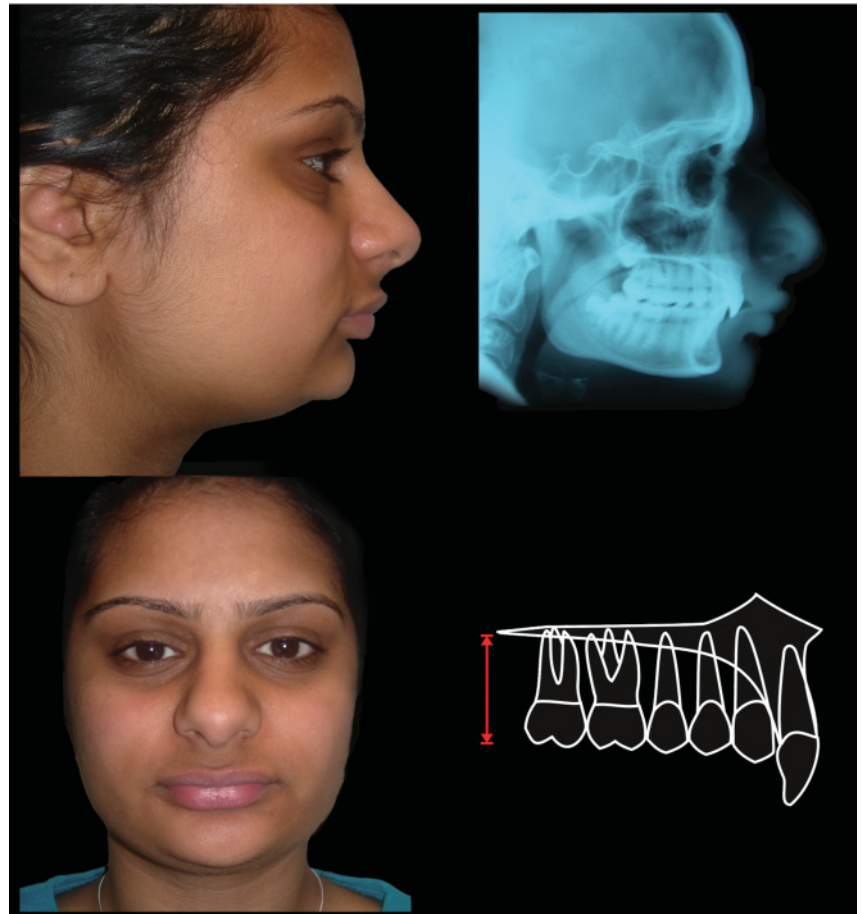


Figure 16.26 Vertical maxillary deficiency (VMD) – example is of a Class II patient with VMD, reduced lower anterior face height (LAFH), low angle (hypodivergent) facial type, reduced gonial angles, prominent lips (lips are effectively squeezed together due to the reduced LAFH), and a deep overbite. The maxillary incisors are overerupted due to the Class II division 2 incisor relationship. There is very little bone between the nasal floor and the root apices of the maxillary teeth.

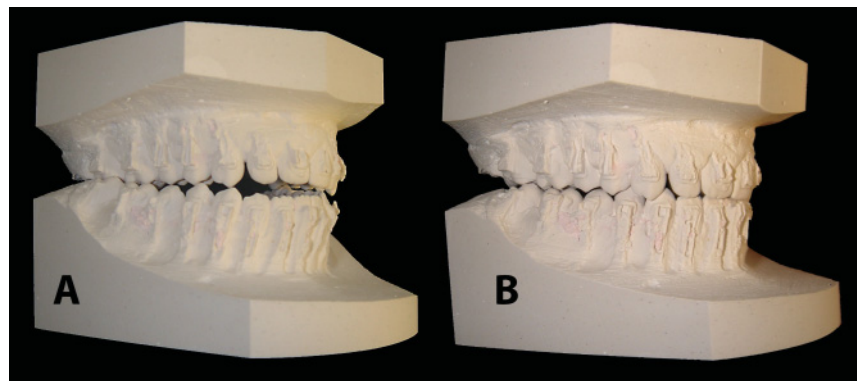


Figure 16.27 Relative transverse maxillary deficiency. (A) Presurgical study casts in occlusion reveal a posterior crossbite tendency. (B) Holding the dental study casts in a Class I canine relationship will reveal no transverse discrepancy.

discrepancy by holding the pre-treatment dental study casts in a post-surgical position may be used to assess whether the transverse deficiency is relative or absolute.

- **Relative transverse maxillary deficiency:** The apparent transverse discrepancy is the result of the sagittal skeletal discrepancy. Holding the dental study casts in a Class I canine relationship will reveal no transverse discrepancy (Figure 16.27).
- **Absolute transverse maxillary deficiency:** This is due to a true transverse skeletal narrowing of the maxilla (Figure

16.28). Holding the dental study casts in a Class I canine relationship will reveal a unilateral or bilateral posterior crossbite.

Principles in planning the correction of maxillary deficiency

The desired sagittal, vertical and transverse position of the maxillary incisors in relation to the upper lip is the cornerstone of treatment planning in maxillary surgery.



Figure 16.28 Absolute transverse maxillary deficiency due to a *true* transverse skeletal narrowing of the maxilla.

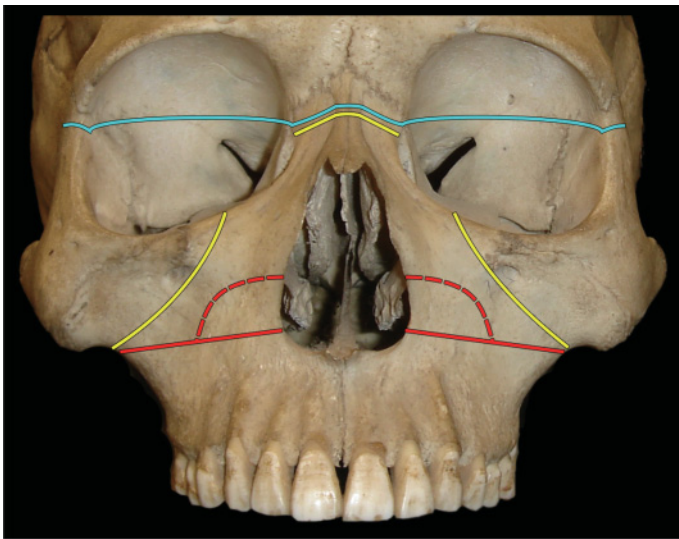


Figure 16.29 Le Fort type osteotomies: Le Fort I type osteotomy (red lines) and higher level Le Fort I type osteotomy (broken red lines); Le Fort II type osteotomy (yellow lines); Le Fort III type osteotomy (blue line).

Sagittal maxillary deficiency: The maxilla may be advanced anteriorly following a Le Fort I type osteotomy. The sagittal position of the maxillary incisors, the upper lip support, nasolabial angle and nasal base support must all be taken into account. Paranasal hollowing, which can extend from the base of the maxillary alveolar process to the infraorbital foramen, may require the Le Fort I type osteotomy to be undertaken at a higher level, in order to augment the paranasal region (Figure 16.29).

Patients presenting with **nasomaxillary hypoplasia** may require Le Fort II type advancement. More extensive midfacial deficiency may require Le Fort III type advancement. Patients with **malar-maxillary hypoplasia**, i.e. marked midfacial deficiency but with normal nasal projection may require the Kufner modification of the Le Fort III type procedure, i.e. simultaneous advancement of the malar-maxillary complex (not involving the nasal bridge but osteotomy extended laterally to include the inferior orbital rim and zygomatic process), or alternatively a Le Fort I type maxillary advancement and separate malar augmentation. Any procedure requiring greater than 10mm advancement may require distraction osteogenesis procedures in order to aid post-treatment stability.

Vertical maxillary deficiency: The maxilla may be inferiorly repositioned by the amount required to achieve between 2mm and 4mm of maxillary incisor exposure with the upper lip at rest, assuming the upper lip height is within normal limits. The planned inferior movement of the maxilla must take into account the maintenance of at least 2–3 mm of freeway space. The resulting posterior, downward and backward rotation of the mandible will reduce sagittal chin prominence. This may well be beneficial to the facial appearance; if not, sagittal and/or vertical chin repositioning may be required.

Transverse maxillary deficiency: In terms of the upper lip-incisor relationship, the maxillary incisors should be coincident with the facial midline, and not angulated to the left or right. In terms of coordination of the maxillary and mandibular transverse widths, the maxillary skeletal and dental arch width may be increased in growing patients using RME; in adults, surgically assisted RME or transverse repositioning of the posterior maxilla following segmental maxillary surgery may be required.

Maxillary excess

Maxillary excess, or excessive maxillary development, may be evident in the sagittal, vertical and transverse planes of space.

Sagittal maxillary excess

Sagittal prominence of the maxilla may be characterized by (Figure 16.30):

- Increased facial convexity.
- Maxillary dentoalveolar protrusion – isolated dentoalveolar protrusion must be distinguished from maxillary prognathism, i.e. excessive prominence of maxillary basal bone.

Note

Sagittal maxillary excess may occur with **midfacial prominence**, which is characterized by prominence of the upper midface, i.e. malar region and inferior orbital rims. Such midfacial prominence often results in **nasal prominence**, although the prominence is due to forward positioning rather than excessive size of the nose. The combination of sagittal mandibular deficiency will make the midfacial prominence even more apparent.

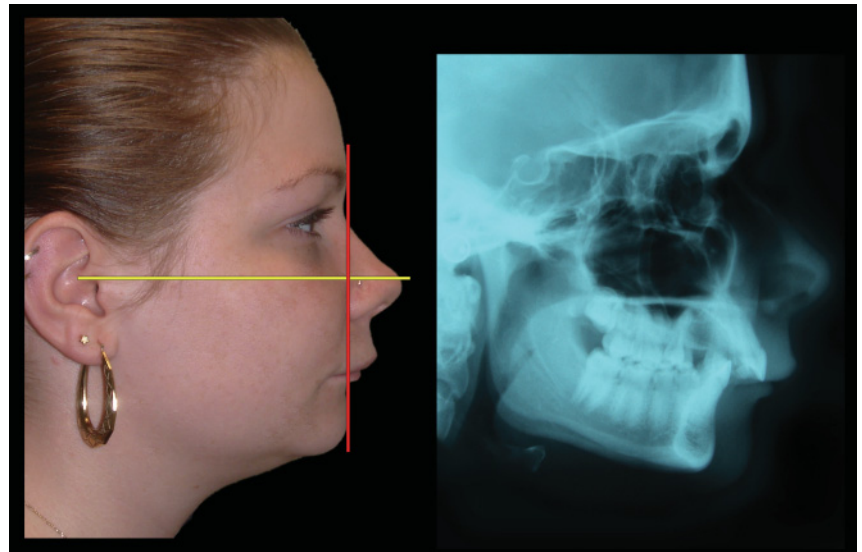


Figure 16.30 Sagittal maxillary excess: soft tissue pogonion is on the true vertical line (red) but subnasale is protrusive.

Vertical maxillary excess

Excessive maxillary development in the vertical plane is termed **vertical maxillary excess (VME)**. Patients with VME tend to exhibit a *predominantly vertical facial growth pattern*, sometimes termed a **long (or tall) face deformity**. The presenting features are:

- Increased total anterior face height (TAFH), almost entirely due to an increased lower anterior face height (LAFH).
- Excessive inferior maxillary skeletal development (VME) – There may be up to 10–15 mm of bone between the nasal floor and the root apices of the maxillary teeth (Figure 16.31). VME may be:
 - **Total VME:** There is excessive vertical development of the entire maxilla, both anteriorly and posteriorly. The maxillary incisor exposure in relation to the upper lip in repose is increased, and on smiling there is increased gingival exposure, or ‘gummy smile,’ both anteriorly and posteriorly (Figure 16.32).
 - **Posterior VME:** There is excessive vertical development of the posterior maxilla and posterior maxillary dentoalveolus (Figure 16.31). There is inferior rotation of the posterior maxilla, i.e. the maxillary plane is canted downward posteriorly. Anterior vertical maxillary dentoalveolar development is often impeded by a forward resting tongue position; therefore, the maxillary incisor exposure in relation to the upper lip at rest may be normal or even reduced.
 - **Anterior dentoalveolar VME:** This, by definition, is not a skeletal basal problem, but a dentoalveolar problem. Excessive overeruption of the maxillary incisors leads to a ‘gummy smile,’ but only anteriorly, i.e. increased anterior gingival exposure on smiling (Figure 16.33). Intrusion of the maxillary incisors and associated gingivae will correct this problem.

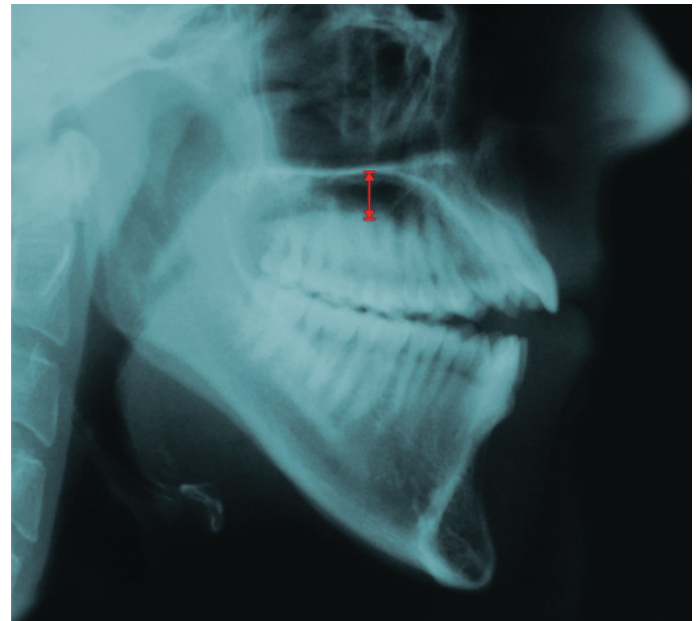


Figure 16.31 There may be up to 10–15 mm of bone between the nasal floor and the root apices of the maxillary teeth if there is excessive inferior maxillary skeletal development; in this case the excessive development in the posterior maxilla exceeds that in the anterior region.

- Upper lip–incisor relationship:
 - Increased exposure of the maxillary incisors in relation to the upper lip in repose, i.e. increased upper incisor exposure
 - Increased dentogingival exposure on smiling, i.e. gummy smile.
- Posterior (downward and backward) mandibular rotation – This will affect the apparent sagittal prominence of the chin. If the mandible is large, the otherwise prominent chin

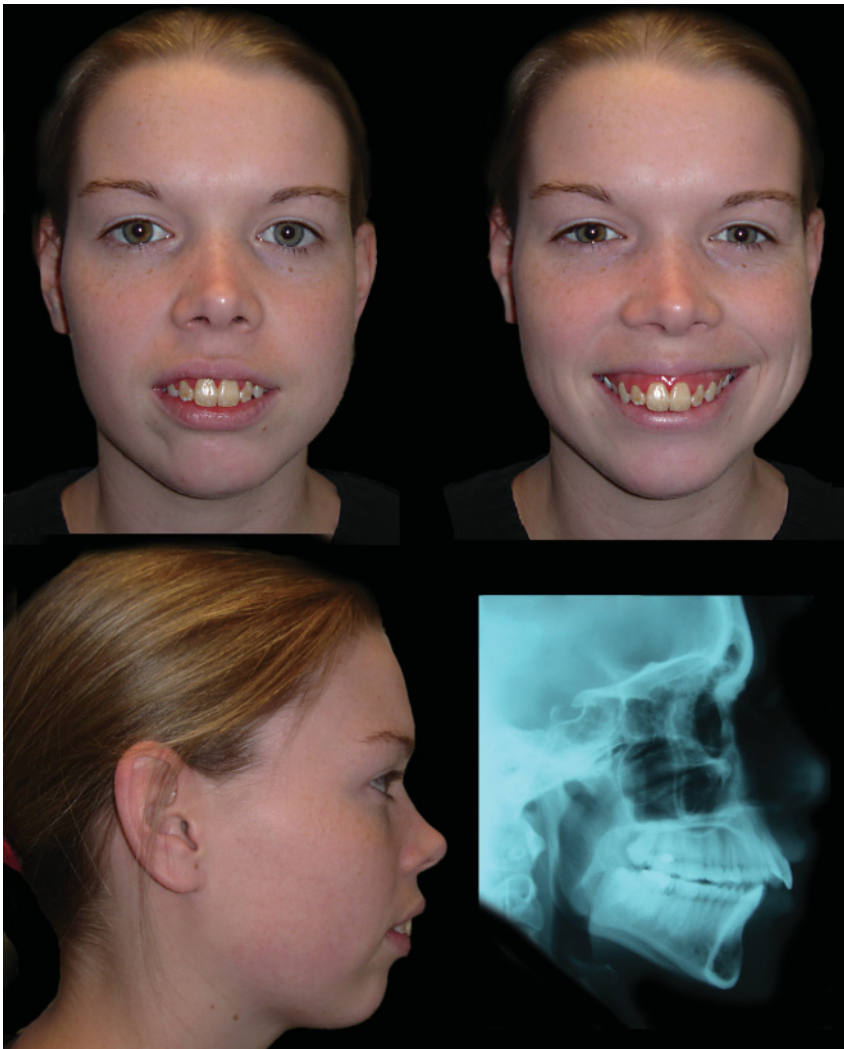


Figure 16.32 Total vertical maxillary excess (total VME): in the presence of normal upper lip height, maxillary incisor exposure in relation to the upper lip in repose is increased, and on smiling there is increased gingival exposure both anteriorly and posteriorly.



Figure 16.33 Excessive overeruption of the maxillary incisors may lead to increased *anterior* gingival exposure on smiling, with normal posterior gingival exposure.

may be rotated to a more normal position in the sagittal plane (skeletal Class III rotated to a skeletal Class I); conversely, and more commonly, if the mandible is of normal or reduced size, the chin will rotate downward and backward to an even less prominent position (skeletal Class I rotated to a skeletal Class II).

- Increased mandibular plane angle; hence the terms **high angle** facial type or **hyperdivergent** face.
- Incomplete lip seal (lip incompetence) – extent depends on lip heights and LAFH.
- Nose: Tendency toward a narrow nose, with a narrow alar base and some paranasal hollowing. It is common for Class II, 'long face' patients to also have a prominent nasal dorsum.
- Palatal vault: Tendency toward high and narrow palatal vault. This may be due to a lower tongue position due to the increased LAFH. Therefore, there is a tendency to posterior dental crossbite.
- Incisor overbite: VME may be associated with **anterior open bite (AOB)**. *When the primary aetiological factor in the presence of an anterior open bite is the excessive face height,*

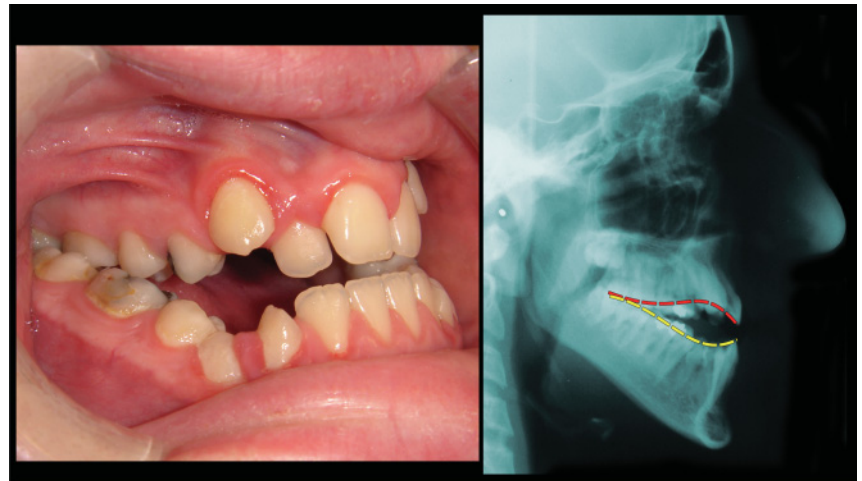


Figure 16.34 A predominantly skeletal aetiology to the anterior open bite, with an increased curve of Spee in the mandibular dental arch and a reverse curve in the maxillary arch.

it is termed a **skeletal open bite**. The extent of an anterior open bite will depend on the LAFH, the degree of compensatory overeruption of the incisor teeth and the resting tongue position.

- If the LAFH is increased and the tongue does *not* have a forward resting position between the incisor teeth, the incisors will overerupt either until they meet, or until they cannot erupt any further. In this situation, the presence of an AOB depends on the LAFH. If the LAFH is excessively increased and the incisors are unable to meet, there will be an AOB, but an increased curve of Spee in the mandibular dental arch and a reverse curve in the maxillary arch (Figure 16.34).

Note

If the incisor teeth are able to vertically compensate for the increased LAFH, there may be a normal or even an increased incisor overbite (Figure 16.35).

- If the tongue has a forward resting position between the incisor teeth, there will be an anterior open bite. In this situation, the presence of the AOB does not depend directly on the LAFH. There is often a reverse curve of Spee in the mandibular arch and an increased curve in the maxillary arch (Figure 16.36).

Note

When an anterior open bite has such additional soft tissue aetiology, the presurgical orthodontic levelling of the maxillary arch will extrude the maxillary incisors and increase maxillary incisor exposure.

Transverse maxillary excess

Maxillary excess in the transverse plane tends to be associated with spacing in the maxillary dental arch (Figure 16.37). Excessive maxillary skeletal width is only a problem if associated with a narrow mandible and a scissors bite.

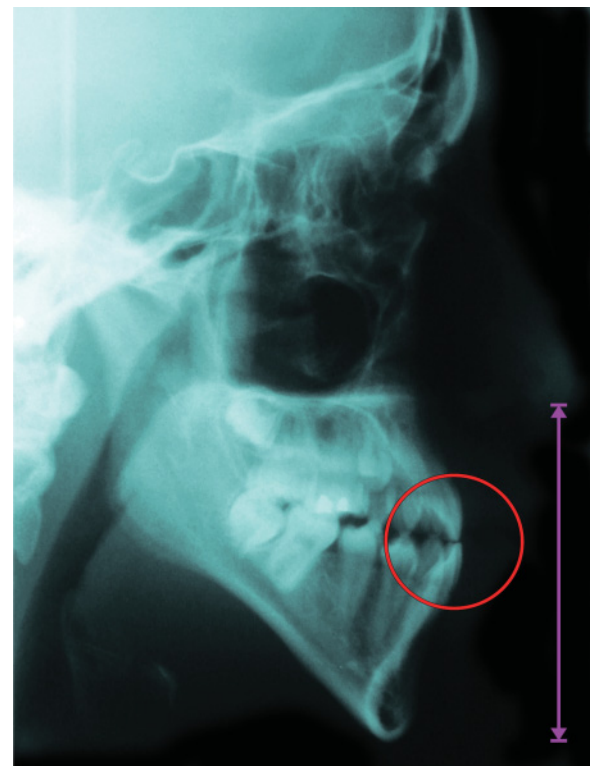


Figure 16.35 Vertical dentoalveolar compensation (incisor overeruption) for the increased lower anterior face height.

Principles in planning the correction of maxillary excess

Excessive vertical facial growth has a very strong genetic determination.¹² The extent and direction of surgical repositioning of the maxilla depends on the extent and direction of the original deformity. *The foundation for treatment planning is the desired upper lip–incisor relationship.*

Sagittal maxillary excess: Orthodontic retraction of the maxillary incisors will have a limited retracting effect on the upper lip,

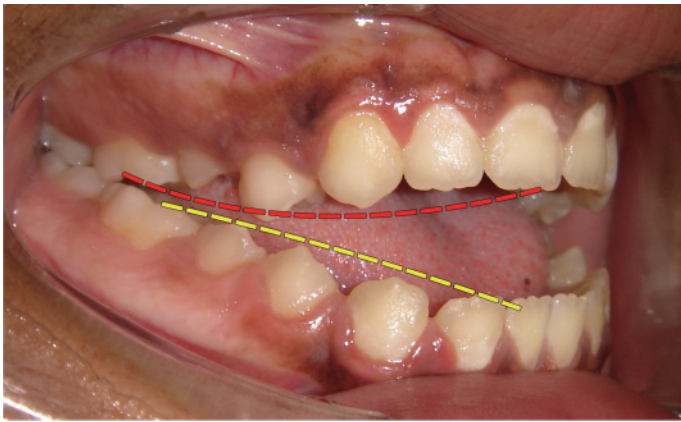


Figure 16.36 A predominantly soft tissue aetiology to the anterior open bite, with a slightly reverse curve of Spee in the mandibular arch and an increased sagittal curve in the maxillary arch.



Figure 16.37 Increased transverse dimensions in the maxilla tend to be associated with spacing in the maxillary dental arch.

which may be beneficial. Posterior surgical repositioning of the entire maxilla following a Le Fort I type downfracture osteotomy is possible by up to 5 mm, by reducing the posterior aspect of the maxillary tuberosities. This may, however, result in some narrowing of the posterior airway. An anterior segmental setback of the maxilla, with the extraction of maxillary premolar teeth is another possibility. With any of these techniques, the potential change in the nasolabial region must be taken into account. It is sometimes better to accept a degree of maxillary dentoalveolar protrusion and advance the mandible, rather than risk excessive prominence of the nose, the creation of an obtuse nasolabial angle and inversion of the vermilion border of the upper lip.

Vertical maxillary excess: The Le Fort I type downfracture osteotomy of the maxilla permits the removal of bone between the nasal floor and maxillary dental root apices, allowing superior repositioning of the maxillary dentoalveolus. The amount of bone removal anteriorly and posteriorly may be altered, e.g. greater bone removal posteriorly permits a greater **differential**

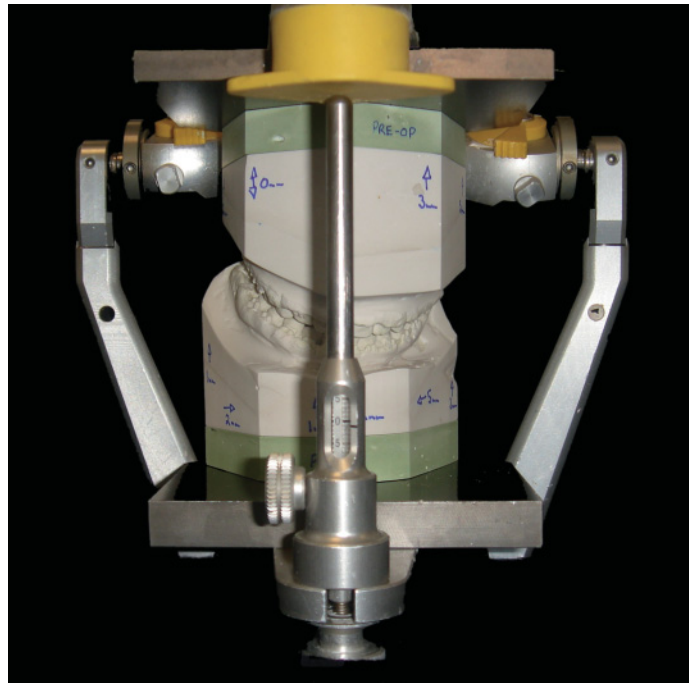


Figure 16.38 Correctly related and well-articulated dental study casts will demonstrate asymmetry in the maxillary occlusal plane – in this example, the presurgical study casts reveal a transverse cant of the maxillary occlusal plane – a result of rotation around the sagittal axis.

impaction of the posterior maxilla.¹³ Alternatively, the posterior maxilla may be segmentally impacted.¹⁴ The mandible rotates anteriorly around the condylar hinge axis, and the chin thereby moves forward and upward. The most important determining factors when planning the extent of maxillary impaction are the resultant upper lip–incisor relationship, which is the mainstay of treatment planning, and the lower anterior facial height.

Maxillary asymmetry

Maxillary asymmetry may be defined as a lack of correspondence in size, shape and/or relative position on opposite sides of a dividing median plane of the maxilla due to disproportionality between the right and left sides of the maxilla. The asymmetry may involve the maxillary skeletal base, the maxillary dentoalveolus and the overlying lower midfacial soft tissues. Maxillary asymmetry may occur due to:

- Rotation around the sagittal axis: This manifests as a transverse cant of the maxillary occlusal plane.
- Rotation around the vertical axis: This usually manifests as a maxillary dental midline deviation.
- Transverse deviation along the transverse (horizontal) plane: This usually manifests as some form of posterior crossbite, which is usually (but not always) unilateral.

These deviations may occur in any combination, and together with asymmetries or deviations in other planes of space of other dentofacial structures, such as the mandible. Thorough clinical

evaluation cannot be overemphasized. Well-oriented clinical photographs with the patient in NHP are very useful, as is posteroanterior cephalometric analysis. However, even slight positional problems when taking the records, particularly rotation of the patient's head around the vertical axis, can produce artificial asymmetries and create significant problems in diagnosis. Therefore, the *most important diagnostic process for patients with maxillary and facial asymmetry involves:*

- **Clinical evaluation:** Particularly analysing the location of the asymmetry, the upper lip–incisor relationship, transverse canting of the maxillary occlusal plane and, if present, the type of posterior crossbite.
- **Correctly related and well-articulated dental study casts** (Figure 16.38): The wax bite recording of the dental occlusion and the facebow record must be very accurately recorded.
- **Three-dimensional reconstructions:** Ideally with superimposition of soft tissues over dentoskeletal structures. As these systems improve, the potential benefit is that the resulting image may be analysed on the computer monitor from different directions.

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Lower Facial Analysis

Introduction

The various dentofacial units which make up the lower third of the face and the upper aspect of the neck are intimately related. However, in addition to analysing the relative position and interrelationships of these units, the size and morphology of each unit and its component subunits must also be evaluated independently.

The dentofacial units that comprise the lower facial third include the lips, mentolabial fold, soft tissue chin, and submental region. The supporting dentoskeletal structures of this region include the maxillary dentoalveolus, the mandibular dentoalveolus, bony chin, mandibular body, and mandibular lower border and gonial angles. The position and height of the hyoid bone and its associated musculature is relevant to the anatomy of the submental region.

Chapter 17 The Lips

Introduction

‘Eternity was in our lips and eyes.’

William Shakespeare, *Antony and Cleopatra* (1606–7)¹

The lips form a transition zone between the facial skin and the oral mucosa and are a significant aesthetic feature of the face (Figure 17.1). They serve important functional roles in phonation and the formation of an anterior oral seal in swallowing. The vermillion of the lips is highly sensitive to light touch sensation and is represented by a large area in the sensory cortex. It is the main exploratory area in babies before they learn to use their hands for stereognosis.

The lips are perhaps the most movable expressive aesthetic unit of the face. Leonardo da Vinci described the importance of the ‘strongly movable section of the face around the mouth and chin in determining facial expression,’ which emphasizes the importance of observing the face in animation as well as in the static state.²

Anatomy

Embryology

The upper lip forms from fusion of the bilateral maxillary processes with the midline medial nasal process. The characteristic morphology of the philtral ridges and Cupid’s bow of the upper lip are a reflection of this developmental process; a cleft lip is a manifestation of this process going wrong (Figure 17.2).

The lower lip forms from the fusion of the two mandibular processes, resulting in a simpler and less defined structure.

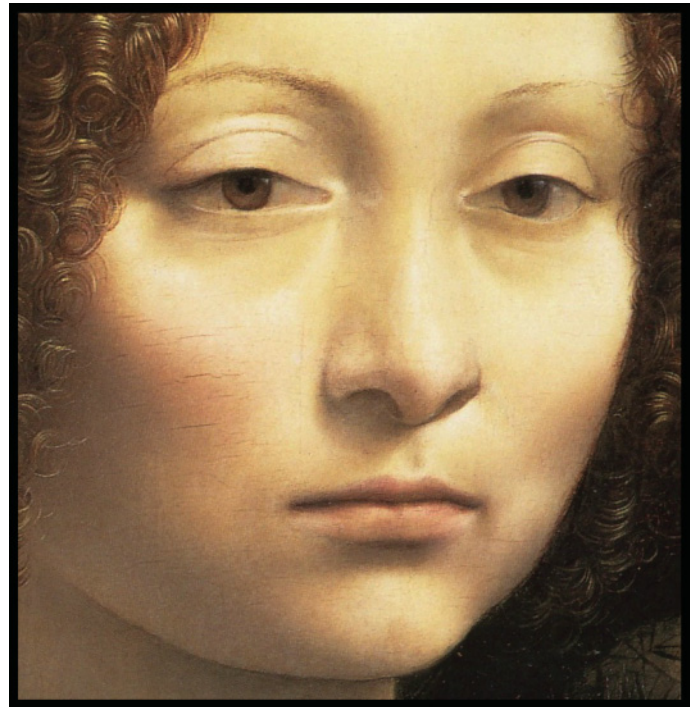


Figure 17.1 The lips are a significant aesthetic unit of the face. (Detail, *Ginevra de' Benci*, c. 1476–8, Leonardo da Vinci, National Gallery of Art, Washington.)

Anatomy

The lips form an aesthetic unit of the face and are anatomically and aesthetically comprised of a number of subunits (Figure 17.3).



Figure 17.2 Repaired right-sided cleft lip.



Figure 17.4 Changes in lip morphology with ageing.

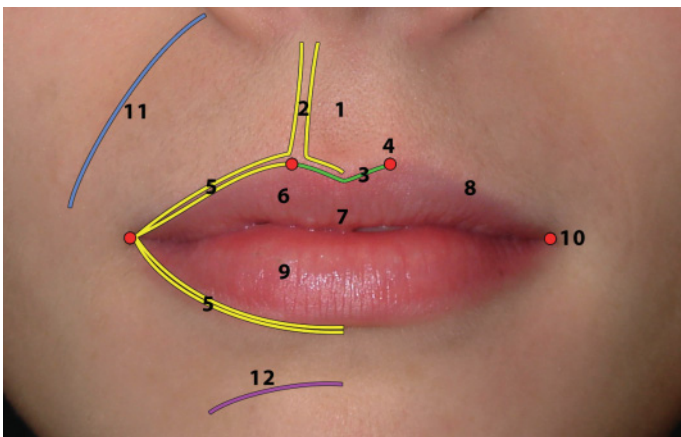


Figure 17.3 Lip anatomy and terminology:

- 1 Philtrum
- 2 Philtral ridges/columns
- 3 Cupid's bow
- 4 High points of the vermillion (bilateral)
- 5 White roll
- 6 Upper lip vermillion
- 7 Upper lip tubercle
- 8 Vermilion border (mucocutaneous junction)
- 9 Lower lip vermillion
- 10 Oral (labial) commissures
- 11 Nasolabial groove
- 12 Mentolabial groove

Philtrum: This is the central region of the upper lip and consists of a shallow vertical groove beneath the nasal columella and between the philtral columns, and the **Cupid's bow**, which is comprised of the two **high points** of the vermillion, corresponding with the inferior end of each philtral ridge, with a 'V'-shaped (hence 'Cupid's bow') depression between them.

Philtral ridges/columns: These are the normal ridges in the skin of the central region of the upper lip that border the philtrum bilaterally, extending bilaterally from the vermillion border of the upper lip to the nasal columella.

White roll/line: This is a raised line of skin, which separates the vermillion from the cutaneous portion of the upper and lower lips. Its function is unknown.

Vermilion and vermillion border: The vermillion of the lips is described as the 'red zone' due to a lack of keratinization and the rich underlying capillary plexus. It is comprised of a dry and a wet portion. The dry part is essentially the visible vermillion of the lip. Its outer border, or vermillion border, separates the vermillion from the cutaneous portion of the lips. Its inner border is termed the **wet line**, separating the dry vermillion from the oral mucosa. The size and morphology of the exposed vermillion is subject to considerable age, sex and ethnic variations.

Commissures: The oral or labial commissures are the angles (corners) of the mouth. The mouth width is the distance between the oral commissures. The oral commissures are an area where the orbicularis oris muscle decussates and the lip elevators, lip depressors and buccinator muscles join.

Note

The lateral boundary of the upper lip on each side is the **nasolabial groove**, which separates the upper lip from the cheek bilaterally. The lower lip is separated from the chin by the **mentolabial groove**.

Ageing

Lip morphology tends to change with advancing age (Figure 17.4). However, the ageing process is exacerbated by extrinsic factors such as excessive sun exposure and smoking. Lip size

tends to increase until puberty, due to muscular and glandular hypertrophy, following which it begins to decrease due to changes in the skin and the supporting tissues, including the muscle, adipose tissue and the maxillary and mandibular dentoalveolus. The following changes tend to occur with the ageing process:

- **Lip height:** The upper lip height increases due to 'sagging', which has a tendency to reduce maxillary incisor exposure; sagging of the lower lip tends to increase mandibular incisor exposure at rest and in animation, particularly in speech.
- **Lip projection:** reduces, due to a reduction in volume of the subcutaneous tissues and reduction in muscle tone.
- **White roll:** The well defined and slightly raised white roll that surrounds the lips flattens.
- **Cupid's bow:** There is loss of definition and blunting of the central defining points and philtrum.
- **Vermilion exposure:** This decreases with age.
- **Commissures:** These become slightly downturned, giving the impression of a frown.
- **Skin:** There is rhytid formation due to loss of volume and loss of skin tone.

Terminology

- **Labial, labio-** (Greek *labium*: lip).
- **Oral, oro-** (Latin *oris*: mouth).
- **Lip protrusion:** Refers to an excessively anterior position of the upper or lower lips relative to the facial profile, particularly the nose and chin. Protrusion of both lips is referred to as **bilabial protrusion**.
- **Lip retrusion:** Refers to an excessively posterior position of the upper or lower lips relative to the facial profile, particularly the nose and chin. Retrusion of both lips is referred to as **bilabial retrusion**.
- **Lip procumbence:** (Latin *procumbere*: 'to fall forwards') a term used to describe a lower lip that is literally 'falling forwards'. Procumbence is a description of lip morphology rather than position. Individuals with mandibular deficiency and reduced lower anterior face height will often have a lower lip that is both retrusive and procumbent.

Clinical evaluation

Systematic clinical evaluation of the lips requires analysis of a number of parameters, which may be conveniently remembered with the acronym LAMPP: lip lines, activity (function), morphology (form), posture and prominence.

Lip lines

Lip lines are defined as the vertical position of the upper and lower lips in relation to the anterior dentition. The 'ideal' dentolabial relationship results when the upper lip covers approximately the upper two-thirds of the maxillary incisor crowns at rest, with 2–4 mm maxillary incisor exposure. The **interlabial**

separation is no more than 2–3 mm (Figure 17.5). The upper and lower lips may be brought into contact with little or no circumoral contraction, with the lower lip covering the incisal third of the maxillary central incisors.

- **High upper lip line:** (sometimes termed a 'high lip line') leads to exposure of the entire clinical crown and associated gingivae of the maxillary incisor teeth, leading to excessive incisor exposure and possibly associated 'gummy' appearance *at rest* (Figure 17.6).

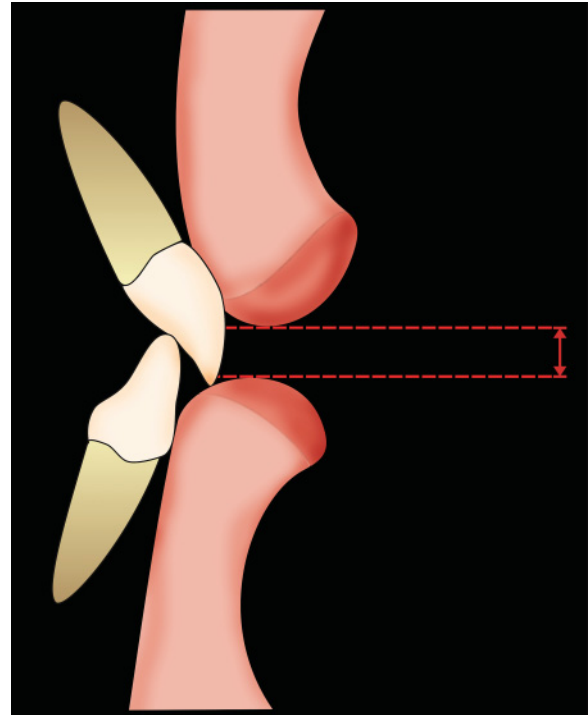


Figure 17.5 Resting lip lines: The interlabial separation is no more than 2–3 mm in repose.



Figure 17.6 High upper lip line.



Figure 17.7 Low upper lip line: The maxillary incisor display may be non-existent at rest and in extreme cases, in speech and in smiling.



Figure 17.8 High lower lip line: The lower lip often rests high on the labial (facial) surface of the maxillary central incisors in Class II division 2 malocclusion, sometimes covering the entire labial surface of the maxillary incisors; pressure from the lower lip is sufficient to retrocline the maxillary central incisors as they erupt.

- **Low upper lip line** (sometimes termed a 'low lip line'): Leads to exposure of less than 2mm of the maxillary incisor crowns. The maxillary incisor display may be non-existent at rest and in extreme cases, in speech and in smiling (the 'no tooth' smile) (Figure 17.7).
- **High lower lip line:** In Class II division 2 malocclusion, the lower lip often rests high on the labial surface of the maxillary central incisors, sometimes covering the entire labial surface, usually as a result of reduced lower anterior face height (LAFH). Pressure from the lower lip is sufficient to retrocline the maxillary incisors as they erupt (Figure 17.8). A hypertonic, strap-like lower lip may even influence the pre-eruptive incisal tooth form via pressure on the alveolar process. The maxillary lateral incisors are shorter teeth and erupt later, thereby escaping the influence of the lower lip and assuming a more labial position.
- **Low lower lip line:** In patients with a Class II skeletal pattern and increased LAFH, the lower lip is unable to provide coverage of the incisal third of the maxillary incisors, allowing the unopposed resting tongue pressure to procline the maxillary incisors.

Clinical evaluation of lip lines is discussed further in Chapter 23.

Lip activity (function)

Lip tonicity

Lip tonicity refers to the **muscular tone** of the lips, related to the production of normal muscular contraction and function. The terms **hypertonic** or **hypertonicity** refer to a state of abnormally high muscle tone, sometimes described as **hyperactivity** or **overactivity**, which is common in Class II, division 2 malocclusion, and tends to retrocline the incisor teeth; in Class II division 1



Figure 17.9 Hypertonicity of the lower lip.

malocclusion a hypertonic lower lip may retrocline the mandibular incisor teeth (Figure 17.9). The term **strap-like lower lip** is sometimes used to describe such overactivity.

The terms **hypotonic** or **hypotonicity** refer to a state of abnormally low muscle tone, sometimes described as **underactivity**. Hypotonicity of the upper lip is common in patients with increased lower face height or severe skeletal Class II jaw relationship combined with lip incompetence (Figure 17.10). The lack of function and hypotonicity is due to the anterior oral seal being formed by the tongue and lower lip, without the contraction of the upper lip. Correction of the underlying deformity allows normal lip function and often results in the upper lip developing normal tonicity. In bimaxillary protrusion and/or proclination the lips tend to be soft and rather limp, sometimes described as **flaccid** (Figure 17.11). These lips as such offer very little resistance to the labial surface of the teeth and may be

involved in the aetiology of the proclination due to the greater tongue pressure on the lingual surface of the incisor teeth.

Dynamic lip evaluation

- **Adaptive anterior oral seal:** Ask the patient to swallow and observe the behaviour of the lower lip for signs of excessive contraction of the mentalis muscle. In swallowing,



Figure 17.10 Hypotonicity of the upper lip.

the lips should normally form a seal (anterior oral seal) in front of the anterior teeth. When this is not possible, adaptive patterns of lip and tongue activity occur in order to form an anterior oral seal. In Class II division 1 malocclusion the lower lip will form a seal behind the maxillary incisors (Figure 17.12). The exaggerated muscular contraction of the lower lip may lead to proclination of the maxillary and retroclination of the mandibular incisor teeth.

- **Hypomobile upper lip:** A thick, fleshy labial frenum may extend from the inner surface of the upper lip becoming attached to the labial surface of the alveolar process. When this attachment is inferior, it may limit the mobility of the upper lip. Management requires an upper labial frenectomy to reposition the frenum.

Lip morphology (form)

Lip height

Lip height, also referred to as lip length, should be evaluated in terms of absolute linear measurements compared with population norms (Table 17.1) and the proportional relationship between the upper and lower lips.

- **Upper lip height:** This is measured from subnasale (Sn) to stomion superius (Sts). Mean upper lip height in adult Caucasians:
 - Male: 22 ± 2 mm
 - Female: 20 ± 2 mm.

Note

With the lips in repose, maxillary incisor exposure in relation to the upper lip is 1–5 mm. Evaluation of the degree of maxillary incisor exposure, which may be related to the vertical position of the anterior maxilla and/or maxillary dentition, must take into account the upper lip height.

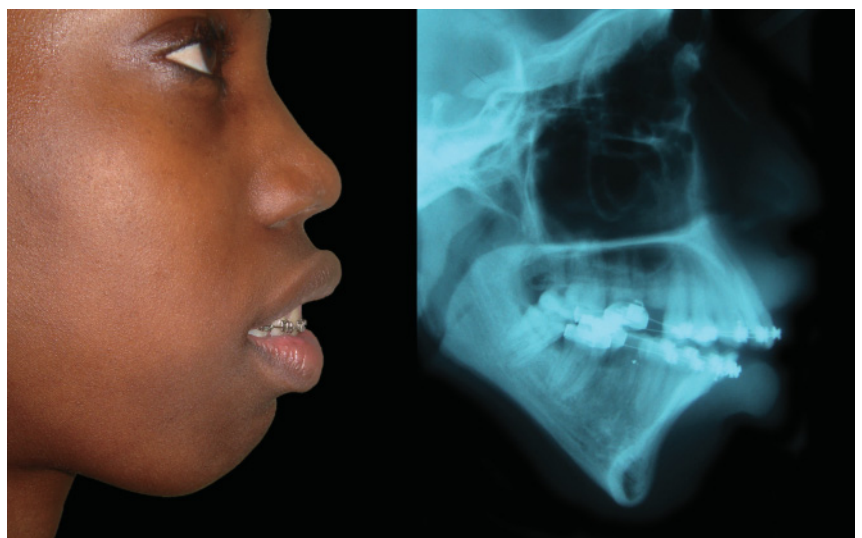


Figure 17.11 Flaccid lips.

Table 17.1 Upper lip height

Study	Caucasian		Oriental (Chinese)*		Black (African American)*	
	Male	Female	Male	Female	Male	Female
Burstone (1967) ³	23.8 ± 1.5 (range: 21.5–26.0)	20.1 ± 1.9 (range: 17.0–23.0)				
Farkas et al. (1984; 1994*) ^{4,5}	21.8 ± 2.2	19.6 ± 2.4	23.5 ± 2.2	21.6 ± 2.1	26.1 ± 2.5	24.5 ± 3.0
Peck et al. (1992) ⁶	23.4 ± 2.5	21.2 ± 2.4				
Bhatia and Leighton (1993) ⁷	21.8 ± 1.7	20.9 ± 2.5				

Mean adult population norms, measured from subnasale to stomion superius, in mm.



Figure 17.12 In Class II division 1 malocclusion the lower lip will form a seal behind the maxillary incisors; this leads to adaptive patterns of lip and tongue activity in order to form an anterior oral seal in deglutition.

- **Lower lip height:** This is measured from stomion (Sto) to sublabiale (Sl):^{4,5}
 - Male: 20 ± 2 mm
 - Female: 18 ± 5 mm.
- **Lower lip/chin height:** This is measured from stomion inferius (Sti) to soft tissue menton (Me'):
 - Male: UK:⁷ 47 ± 3 mm (USA:^{4,5} 51 ± 4 mm)
 - Female: UK:⁷ 44 ± 3 mm (US:^{4,5} 43 ± 3 mm).

Note

An increased lower lip/chin height may be due to increased vertical skeletal chin height and/or lower lip height.

- **Ratio of upper lip to lower lip/chin height:** Upper lip height may be anywhere between approximately a third (according to Leonardo da Vinci) to a quarter (according to Albrecht

Dürer) of lower lip/chin height (see Chapters 2 and 9). *Well-proportioned upper to lower lips are more important than absolute lip heights.*

- **Interlabial gap:** With the mandible in rest position and the lips in repose, the interlabial gap may be between 0 and 3 mm. An interlabial gap of greater than 4 mm is usually an indication of an incomplete lip seal (lip incompetence).
- **Upper and lower lip vermillion height:** Vermilion height and exposure tends to vary quite considerably, both individually and between the sexes and different ethnicities (Figure 17.13).
 - The ratio of upper lip vermillion height (Ls-Sts) to lower lip vermillion height (Sti-Li) is approximately 3:4
 - Vermilion height of upper lip:^{4,5} 8–9 ± 1 mm
 - Vermilion height of lower lip:^{4,5} 10 ± 2 mm
 - The ratio of vermillion exposure height to lip height tends to be greater in females, i.e. women have *proportionally* greater vermillion exposure.

Note

An understanding of the proportional relationship of the upper to lower lip vermillion height is important when planning vermillion enhancement/augmentation. If the upper lip vermillion exposure is made greater than the lower lip vermillion, the created disproportion gives the patient a 'fish-like' appearance, particularly if the upper lip is also made excessively prominent. This unfortunately commonly seen appearance demonstrates the importance of understanding proportional relationships.

- **Influence of growth and soft tissue lip maturation:** The increase in lip height that occurs during growth does not perfectly match vertical growth of the lower face. Increase in lip height tends to lag behind vertical jaw growth prior to the adolescent growth spurt when it catches up. Upper and lower lip height continues to increase during adolescence, with males having greater growth than females. Increase in upper lip height tends to plateau at 14 years in females, whereas it



Figure 17.13 Variation in vermilion heights.

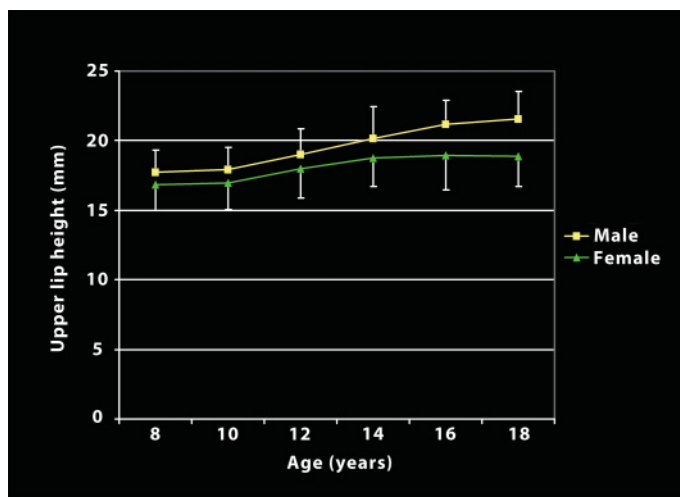


Figure 17.14 Change in upper lip height with growth from ages 8 to 18 (error bars represent the standard deviation of the mean changes); data from Mamandras;⁸ based on original serial cephalometric data from the Burlington Growth Centre (sample of 32 untreated children with Class I dental and skeletal patterns).

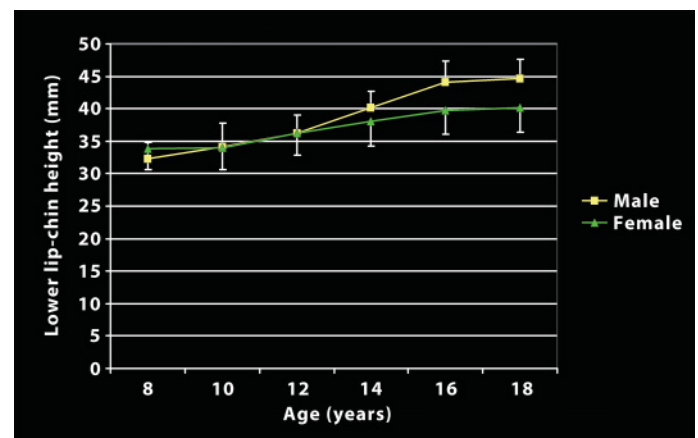


Figure 17.15 Change in lower lip-chin height with growth from ages 8 to 18 (error bars represent the standard deviation of the mean changes); data from Mamandras;⁸ based on original serial cephalometric data from the Burlington Growth Centre (sample of 32 untreated children with Class I dental and skeletal patterns).

may continue until age 18 in males (Figure 17.14).⁸ Vertical growth of the lower lip plateaus in both sexes at 16 years of age and exceeds growth in the upper lip (Figure 17.15). Therefore, a relatively short upper lip and lip 'incompetence' in a child will improve during adolescence, *provided* the skeletal and soft tissue growth pattern is normal. Such **age variation** must be taken into account when treatment planning and maxillary incisor intrusion should usually be avoided in younger patients, otherwise with age it may result in reduced incisor exposure, which is unattractive.

Lip thickness

The thickness of the lips is an important parameter in the evaluation of lip morphology and is correlated with lip prominence. It is also an important factor to take into account in treatment planning incisor retraction/protraction or surgical advancement/retropositioning of the jaws; thinner lips tend to follow the teeth and jaw movements whereas thick, flaccid lips may alter position only slightly.

- **Upper lip thickness:** This may be measured horizontally from a point on the anterior aspect of the maxillary alveolar process, 2 mm below A-point (to avoid the influence of nasal structures), to the anterior surface of the upper lip. Ideal upper lip thickness is 15 mm (Figure 17.16A).^{9,10}

Note

The upper lip thickness should also be measured from the labial surface of the maxillary incisors to the vermilion border of the upper lip. This should be approximately the same as the upper lip thickness described above (± 1 mm). If lip seal is achieved by circumoral muscular contraction, this measurement will be less than upper lip thickness, and the upper lip is considered strained (**upper lip strain**) (Figure 17.16B). Nevertheless, it is important to take lateral cephalometric radiographs with the lips in repose, in which case lip strain will not be evident.

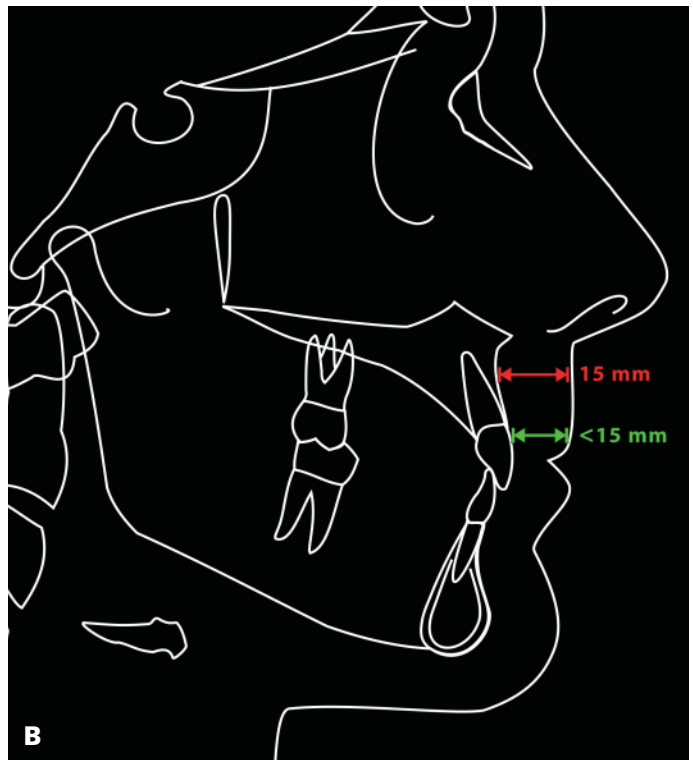
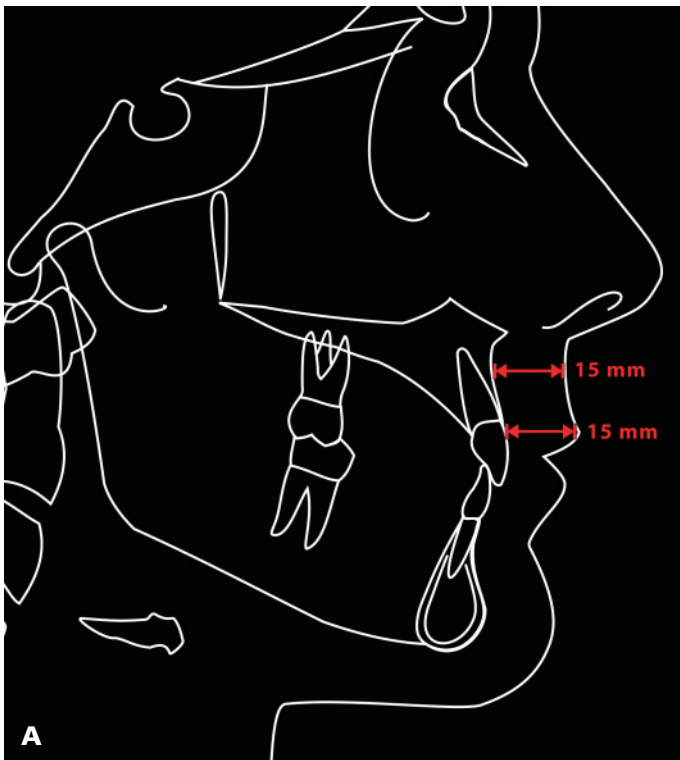


Figure 17.16 (A) Upper lip thickness. (B) Upper lip strain.

Note

The total chin thickness, measured as the effective bony chin ahead of the nasion-B point (NB) line and the thickness of the soft tissue chin pad should equal the upper lip thickness (Figure 17.17).

- **Lower lip thickness at vermilion border** (Figure 17.18A): This may be measured horizontally from infradentale to the vermilion border of the lower lip. Normal values are:⁷
 - Male: 15 ± 1.5 mm
 - Female: 12.5 ± 1.0 mm.

Note

Holdaway^{9,10} gives a value of 10 mm for ideal lower lip thickness.

- **Lower lip thickness at B-point** (Figure 17.18B): This may be measured horizontally from skeletal B-point to soft tissue B-point (sublabiale). Normal values are:⁷
 - Male: 10 ± 1.0 mm
 - Female: 9.5 ± 1.0 mm.
- **Ethnic variation:** Lip thickness is influenced to a great extent by ethnic background. Caucasians of northern European backgrounds have relatively thin lips compared with Caucasians of eastern European or Middle Eastern

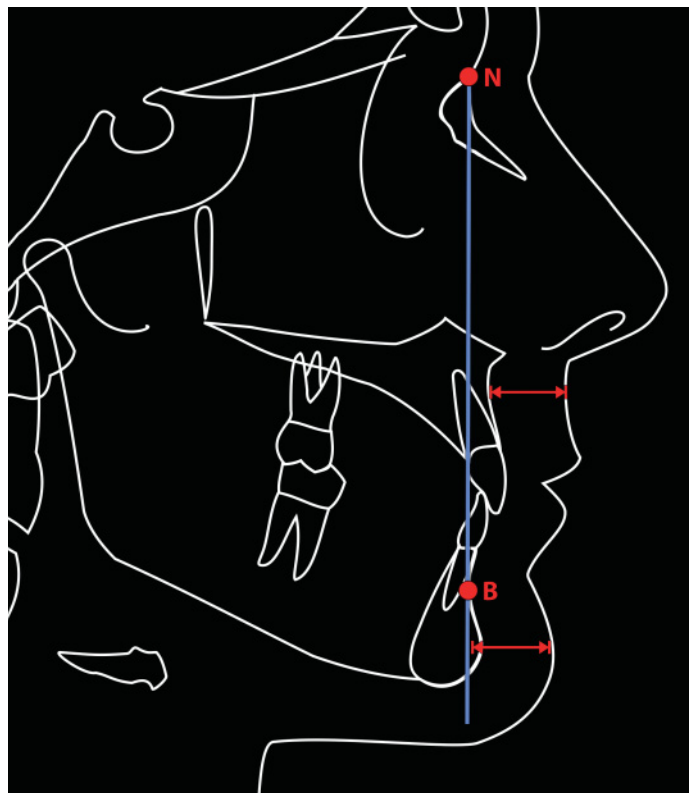


Figure 17.17 Total chin thickness (effective bony chin ahead of the NB line and the thickness of the soft tissue chin pad) should equal the upper lip thickness.

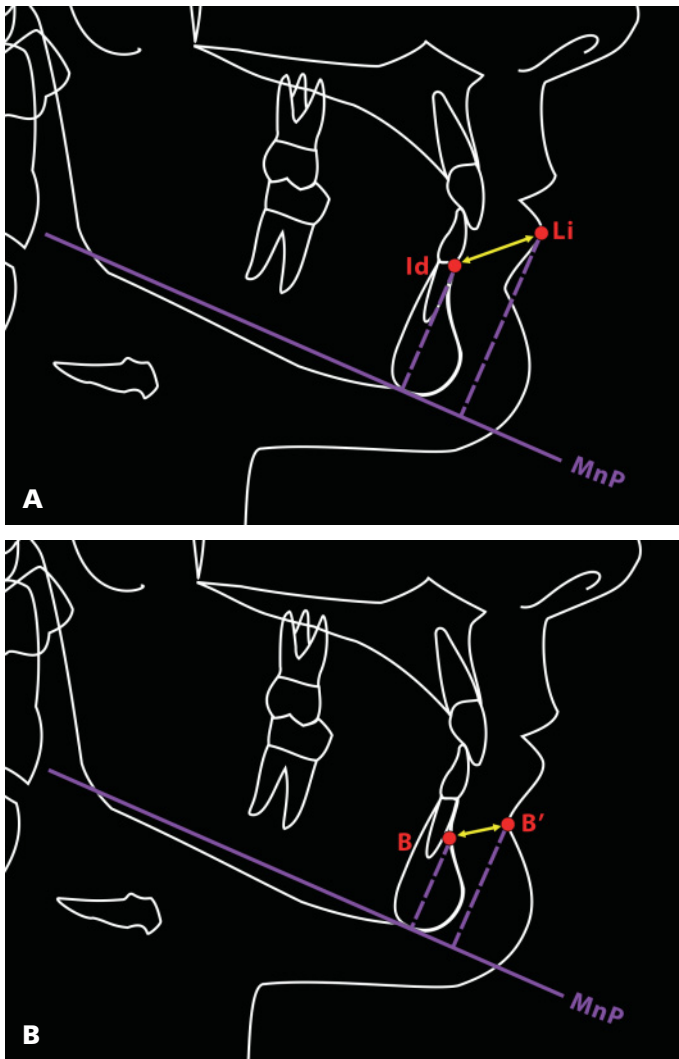


Figure 17.18 (A) Lower lip thickness at vermilion border. (B) Lower lip thickness at B-point, which is effectively a measure of soft tissue thickness in the mentolabial fold region.

origin. Black individuals often have the greatest degree of lip thickness, coupled with an increased propensity for den-toalveolar protrusion, leading to an overall more bilabial protrusive appearance.

- **Influence of growth and soft tissue lip maturation** (Figures 17.19 and 17.20): Growth in upper and lower lip thickness tends to plateau by approximately the age of 16 years in males and females. In females, upper lip thickness reaches a maximum at age 14, and in males at age 16; in both sexes lip thickness begins to reduce after 16 years of age. Lower lip thickness reaches a maximum by age 15 years in both males and females.⁸

Lip contour

Lip contour may be evaluated in frontal and profile view. In frontal view, the lips are evaluated for **curvature**. In profile view, the lips are evaluated for lip **curl** (anterior curvature) and **inclination** (sagittal cant).

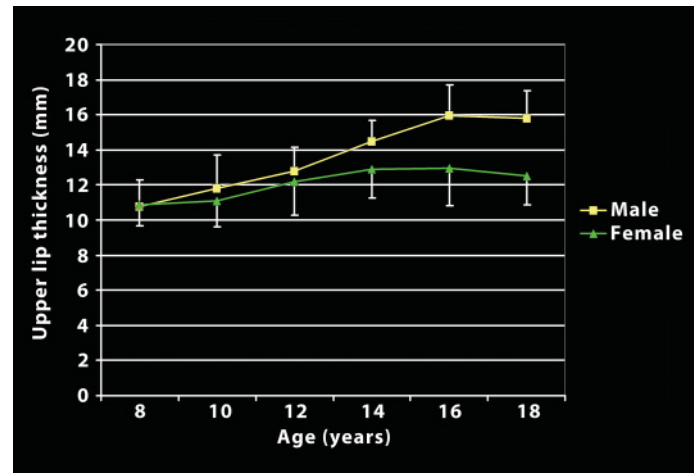


Figure 17.19 Change in upper lip thickness with growth from ages 8 to 18 (error bars represent the standard deviation of the mean changes); data from Mamandras;⁸ based on original serial cephalometric data from the Burlington Growth Centre (sample of 32 untreated children with Class I dental and skeletal patterns).

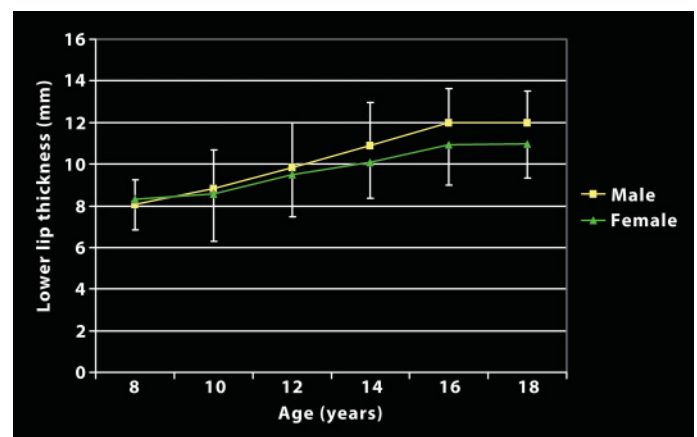


Figure 17.20 Change lower lip thickness with growth from ages 8 to 18 (error bars represent the standard deviation of the mean changes); data from Mamandras;⁸ based on original serial cephalometric data from the Burlington Growth Centre (sample of 32 untreated children with Class I dental and skeletal patterns).

Lip curvature (frontal view)

The *contour of the upper lip* at rest in frontal view depends mainly on the differential height of the mid-philtrum and the bilateral oral commissures. The philtrum is measured from subnasale (Sn) to stomion superius (Sts: the most inferior point of Cupid's bow). The **commissure height** is measured from each oral commissure perpendicular to a horizontal line drawn through subnasale.

- In children and adolescents the philtrum height is often several millimetres shorter than the commissure height.
- Due to differential vertical growth of the philtrum and oral commissures, the mid-philtrum height and bilateral oral commissure heights should be approximately equal in adults with the lips lightly in contact.^{11,12} The mid-philtrum height

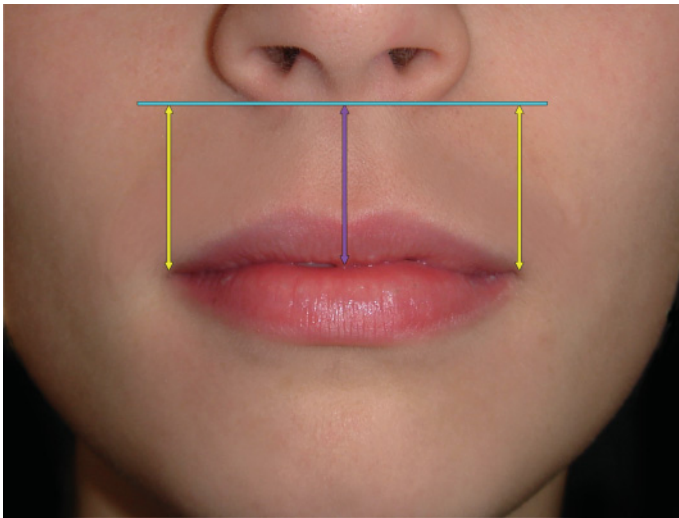


Figure 17.21 Upper lip curvature (frontal view): the mid-philtrum height and bilateral oral commissure heights should be approximately equal in adults with the lips lightly in contact.

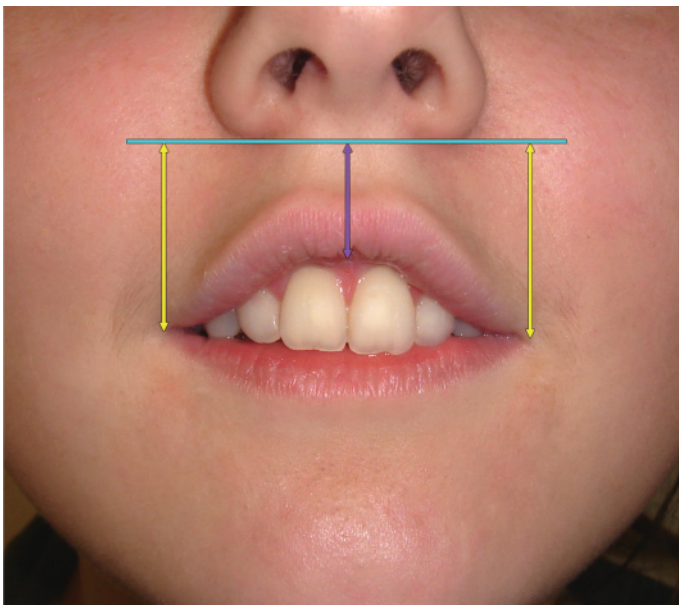


Figure 17.22 A significantly shorter mid-philtrum height compared with commissure height in an adult result in upper lip line morphology referred to as an inverted arc.

may be approximately 1–3mm shorter than commissure height with the lips in repose (Figure 17.21).

- A significantly shorter mid-philtrum height compared with commissure height in an adult result in unattractive upper lip line morphology referred to as an **inverted arc** (Figure 17.22). The reduced philtrum height may be increased with V-Y cheiloplasty.

The *contour of the upper and lower lips* at rest may resemble an inverted arc in a number of conditions, giving the patient the appearance of a frown:



Figure 17.23 Reduced upper lip curl: posterior sagittal curvature of the upper lip, with the vermilion border further posterior than the base of the upper lip.

- **Maxillary or midfacial hypoplasia:** The unintentionally aggressive appearance particularly common in ‘Class III’ patients is due to this inverted arc, secondary to maxillary hypoplasia. Management requires maxillary advancement.
- **Lowering/drooping of the oral commissures** as a result of ageing: Management requires rhytidectomy (facelift).

Lip curl (profile view)

Mild sagittal anterior curvature or ‘curl’ of the upper lip in profile view is an important aesthetic consideration.

- **Reduced curl:** A flat upper lip or a reverse, posterior curvature may occur in maxillary retrognathia and/or maxillary dentoalveolar retrusion due to lack of dentoskeletal support for the upper lip, or due to lip strain in individuals with incompetent lip posture attempting to create a lip seal (Figure 17.23).

Note

Excessive, incorrectly planned and poorly controlled orthodontic retraction of the maxillary incisors may allow the upper lip to drop back, *more at the vermilion border than at the base*, tending to flatten the upper lip. However, lip position changes less than tooth position and the relationship varies considerably in different individuals depending on lip thickness and tone.

- **Excessive curl:** This may be due to a reduced lower anterior face height (LAFH) and/or mandibular overclosure with the

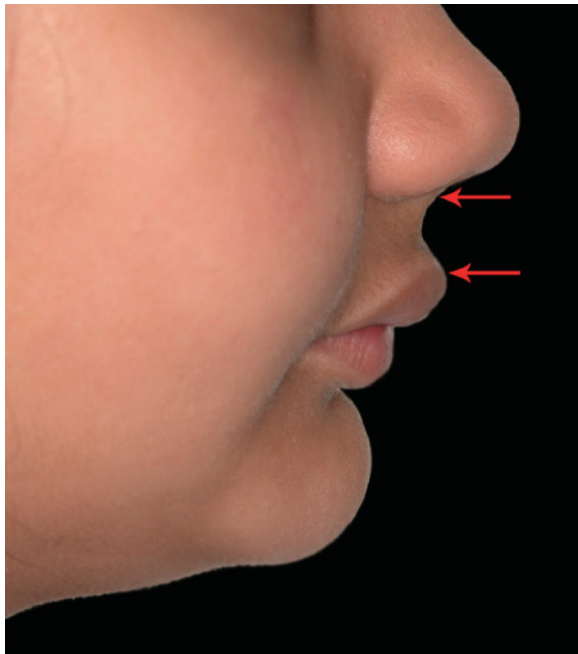


Figure 17.24 Increased upper lip curl.

lips compressed together (Figure 17.24). Eversion of the lower lip may also be due to proclined maxillary incisors in Class II division 1 incisor relationship. Correction of the incisor relationship allows the lower lip to lie in front of the maxillary incisors, thereby reducing the curvature of the lower lip.

Evaluation of upper lip curl may be undertaken as follows: a line is drawn from labrale superius (Ls) to subnasale (Sn). The depth of the upper lip concavity from this line should measure between 1 mm and 3 mm (Figure 17.25).^{13–15}

The upper lip sulcus depth may also be measured from the H-line of Holdaway (Figure 17.26):^{9,10}

- 5.0 mm (normal lips).
- Between 3.0 mm and 7.0 mm (depending on if lips are thin or thick, respectively).

The lower lip sulcus depth may also be measured from the H-line of Holdaway:^{9,10}

- 5.0 mm (normal lips).

Lip inclination

Upper lip inclination

- **Upper lip inclination to nasion-perpendicular (McNamara):** The inclination of the upper lip may be evaluated using a line tangent to the upper lip (labrale superius to subnasale) extended to intersect the nasion-perpendicular (see Figure 16.13). The angle should be:¹⁶
 - Male: $8^\circ \pm 8^\circ$
 - Female: $14^\circ \pm 8^\circ$.
- **Upper lip inclination to true horizontal plane:** The inclination of the upper lip may be evaluated using a line tangent

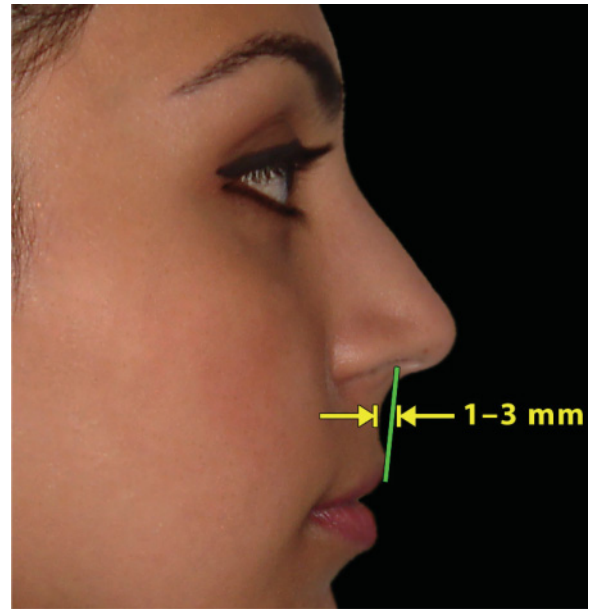


Figure 17.25 Evaluation of upper lip curl may be undertaken by drawing a line from labrale superius (Ls) to subnasale (Sn). The depth of the upper lip concavity from this line should measure between 1–3 mm.

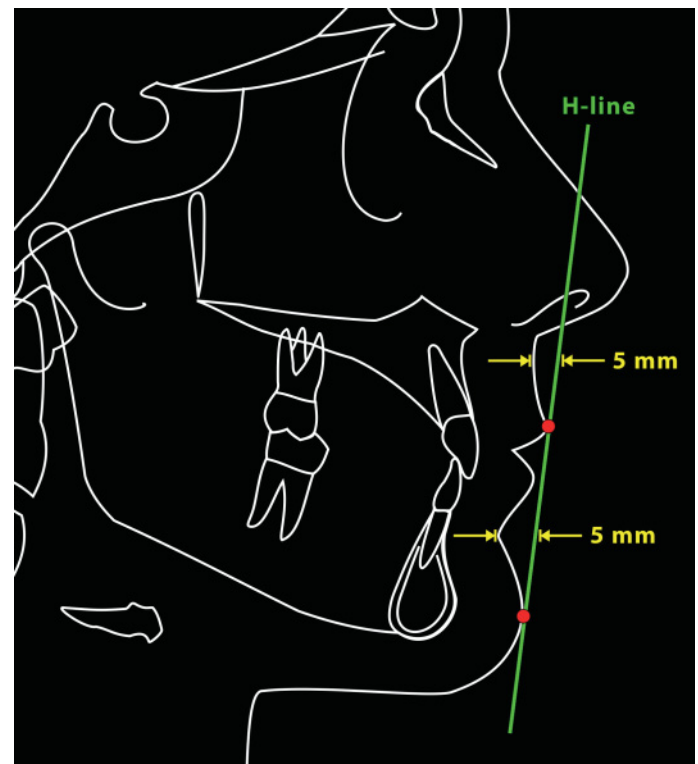


Figure 17.26 Upper and lower lip sulcus depths may be measured from the H-line of Holdaway.

to the upper lip (labrale superius to subnasale) extended to intersect the true horizontal plane. The posteroinferior angle should be approximately:

- 90–95° (up to 110°).

- **Nasolabial angle (lower component):** The nasolabial angle is formed by drawing a line tangent to the nasal columella (columella tangent) and a line tangent to the upper lip (upper lip tangent). This angle will depend on the inclination of the nasal columella *and* the upper lip. To better assess the inclination of the upper lip, the nasolabial angle may be separated into upper and lower component parts using a true horizontal line through subnasale. This will allow the columella tangent-true horizontal plane and the upper lip tangent-true horizontal plane angles to be assessed separately, as they *vary independently*. Average values for upper lip tangent to true horizontal plane are (see Figure 16.14):
 - $85^{\circ 17}$
 - $88\text{--}92^{\circ}$ (indirectly calculated from original data provided by Farkas).⁵

Lower lip inclination

- **Mentolabial angle (upper component):** This is described fully in Chapter 18.

Lip posture

Lip posture may be defined as the characteristic way in which an individual, in natural head position (NHP), maintains their normal lip position in repose, i.e. with normal muscular tone and without excessive muscular contraction. The orolabial soft tissue posture is characteristic of each individual and, under normal conditions each individual will achieve a lip seal in the

rest position. If a lip seal does *not* occur, adaptive postures are used with almost continual contraction of the circumoral musculature in order to maintain an adequate lip seal. The formation of lip seal at rest is termed complete lip seal (or lip competence) and excessive lip separation at rest is termed incomplete lip seal (or lip incompetence).

- **Complete lip seal (lip competence):** Competent lip posture implies adequate lip seal, with the lips able to contact one another without strain when the mandible is in rest position.
- **Incomplete lip seal (lip incompetence):** Incompetent lip posture occurs when the lips are unable to form an adequate seal under similar unstrained conditions, i.e. excessive separation of the lips at rest (Figure 17.27). Proffit¹⁸ has stated that as a general guideline, which holds for all ethnic groups, lip separation at rest should be no more than 3–4 mm; above this, the lips are termed incompetent.

Note

Patients with mild lip incompetence often maintain a lip seal by slight circumoral contraction for a significant portion of the time; this can sometimes be difficult to detect. The revelatory signs are a *flattening of the mentolabial fold* and, with more severe lip incompetence, the appearance of *corrugations* over the anterior surface of the chin where the fibres of the mentalis muscle, responsible for lip elevation, are inserted (Figure 17.28).



Figure 17.27 (A) Incomplete lip seal (lip incompetence) refers to excessive separation of the lips in repose. (B) Patients with mild lip incompetence often maintain a lip seal by slight circumoral contraction for a significant portion of the time.



Figure 17.28 With more severe lip incompetence, as well as flattening of the mentolabial fold there is the appearance of corrugations over the anterior surface of the chin where the fibres of the mentalis muscle, responsible for lip elevation, are inserted.



Figure 17.29 Potential lip competence.

- **Potential lip competence:** The maxillary incisors may be interposed between the upper and lower lips. Such lip posture is termed potentially competent or 'pseudo-incompetent', as correction of the incisor relationship will permit normal lip posture (Figure 17.29).

Note

It is important for clinicians to avoid using the terms lip 'incompetence' or 'incompetent' *in the presence of patients*, as this may result in causing unintentional offence. Terms such as 'incomplete lip seal' or 'lips apart at rest' are preferred.

The ability to achieve lip seal in repose (lip competency) depends on a number of factors:

- **Soft tissue factors:**
 - **Lip height:** Reduced lip height may prevent normal lip competence.

Note

Habitually parted lips are more common in children partly due to differential growth in lip height and lower anterior face height (LAFH). Relative lip growth tends to exceed growth in the LAFH, thereby increasing lip 'competence' with age.¹²

- **Lip morphology:** Thick, flaccid lips have a tendency to 'hang open'.
- **Soft tissue chin pad:** Competent lip posture is functionally related to the soft tissue contour of the chin. Increased contraction of the complex interwoven muscular network anterior to the bony symphysis, particularly the mentalis muscle, which elevates the lower lip, may lead to unattractive corrugations of the skin over the muscle insertion, described as wrinkling and dimpling, and/or hypertrophic bunching of the muscle mass and overlying skin.

- **Skeletal factors:**

- **Sagittal skeletal discrepancy:** Significant Class II or Class III skeletal pattern will make achievement of a lip seal difficult.
- **Increased lower anterior face height:** Even if lip height is adequate, with an increased LAFH the lips may not be able to meet.

- **Dentoalveolar factors:**

- **Dentoalveolar protrusion:** Bimaxillary dentoalveolar protrusion means that the teeth in both jaws are protrusive. In such cases it is often difficult for the patient to achieve a lip seal over the protruding incisors. Such a condition may be iatrogenic, if having been poorly diagnosed, crowded dentitions are aligned orthodontically on a non-extraction basis, leading to their excessive protrusion.
- **Incisor proclination:** Excessive bimaxillary incisor proclination may lead to the same problem described above.

Lip prominence

A number of terms may be used to describe lip prominence, including sagittal position, projection, protrusion or retrusion. The prominence of the lips is visually evaluated *relative* to the prominence of the nose and chin. In fact, in profile view, the prominence of the nose, lips and chin are all *relative* to one another.

Aetiology of lip prominence

The aetiology of the prominence of the lips depends on a number of factors.

- **Soft tissue factors:**

- **Morphology and thickness of the lips:** Thick, flaccid lips are more prominent than thin lips. If the enlargement and prominence of the lips is due to the morphology and thickness of the lips, significant improvement may be obtained by excision of an elliptical wedge of soft tissue behind the margin of the wet line (the area of lip mucosa behind the lip seal region), varying in width depending on the amount of reduction required.

Note

In cases where the lip prominence is due to the underlying dentoalveolar protrusion, surgical lip reduction will not achieve the desired improvement without correction of the incisor position.

- **Skeletal factors:**
 - A reduced lower anterior face height may compress the upper and lower lips together, leading to protrusion of



Figure 17.30 Maxillary dentoalveolar protrusion: such protrusion of the maxillary dentoalveolar processes relative to the basal bone may lead to excessive prominence of the upper lip.

the lips. Increasing the LAFH may in itself correct the lip prominence when this is the underlying aetiological factor.

- **Dentoalveolar factors:**
 - **Sagittal position of the incisor teeth:** An important factor, providing support to the lips by the dentition:
 - **Maxillary and/or mandibular dentoalveolar protrusion** (Figure 17.30): Protrusion of the dentoalveolar processes relative to the basal bone of the maxilla and mandible.
 - **Maxillary and/or mandibular dentoalveolar retrusion:** Retrusion of the dentoalveolar processes relative to the basal bone of the maxilla and mandible.

Note

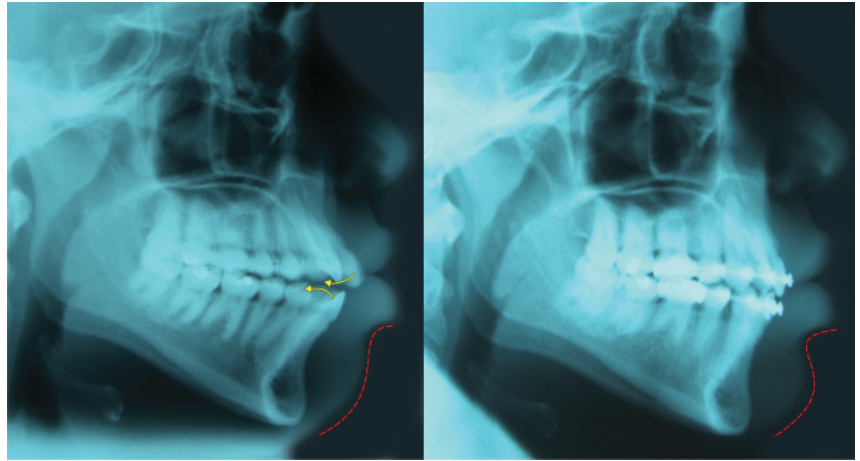
Dentoalveolar protrusion/retrusion is not to be confused with maxillary and/or mandibular prognathism or retrognathism, which is the protrusion or retrusion of the basal bone of the maxilla and mandible.

- **Inclination of the incisor teeth:**
 - **Maxillary and/or mandibular incisor proclination:** Proclination of the incisors will tend to make the lips more prominent, particularly if the lips are thin (Figure 17.31). The effect on thick, flaccid lips tends to be minimal.
 - **Maxillary and/or mandibular incisor retroclination:** Retroclination of the incisors will tend to cause lip retrusion, sometimes referred to as 'flattening' or 'dishing-in' of the lower facial profile. This may occur if premolar extractions are planned due to incorrect diagnosis and incisor retroclination or retraction occurs due to poor technical orthodontic treatment. Nevertheless, the effect will depend to a great extent on the morphology and thickness of the lips.



Figure 17.31 Proclination of the maxillary incisors will tend to make the upper lip more prominent, particularly if the lip is thin.

Figure 17.32 Excessive dentoalveolar protrusion and proclination in the presence of lip incompetence; circumoral contraction is required to maintain a complete lip seal (lip competence). In such cases, retraction and retroclination of the incisor teeth improves lip posture.



Note

Lip prominence is related to excessive dentoalveolar protrusion and/or proclination *in the presence of lip incompetence*. In such cases, retraction of the incisor teeth will improve lip posture and reduce lip prominence, improving the facial profile (Figure 17.32). However, if the lips are prominent but lip seal can be achieved without lip strain (competent lip posture), the lip posture is due to the morphology of the lips and will not alter with changes in incisor position.

Evaluation of lip prominence

Evaluation should be undertaken with the patient in natural head position (NHP), the mandible in the rest position and the lips in repose.

Note

Each analysis used in facial evaluation requires one or more reference lines, which are formed by joining some reference landmarks or points (other than the true horizontal and true vertical lines). Therefore the effectiveness and practicality of each analysis depends on whether the selected reference points are in 'ideal' positions, and thereby depends significantly on the presenting craniofacial deformity. For example, the sagittal position of the chin may be related to a perpendicular line from the true horizontal (or Frankfort Horizontal) plane through subnasale, but this will only be useful if the sagittal position of subnasale is correct.

A number of analyses have been described, which aid in the evaluation of the *relative prominence* of the upper and lower lips to the facial profile, in particular to the nose and chin. These include (Figure 17.33):

E-line (Ricketts): Upper and lower lip prominence may be measured in relation to the 'Esthetic' (nose-chin) line, drawn from pronasale (Prn) to soft tissue pogonion (Pog').^{19,20} This

measurement is highly dependent on nasal tip and chin projection.

- In white Caucasians the average values are:
 - Upper lip (labrale superius, Ls): –4 to –6 mm behind E-line
 - Lower lip (labrale inferius, Li): –2 to –4 mm behind the E-line.
- Influence of age: At age 10 the lips are only slightly behind the E-line. Subsequent growth of the chin and in particular the nose carries the E-line forwards away from the lips during growth. On average, the upper lip drops back approximately 0.4 mm/year relative to the E-line during growth; the lower lip drops back 0.2 mm/year. If at age 10 the lips are significantly behind the E-line, the lower facial profile is likely to remain or become more retrusive with growth.
- Influence of sex: Slightly greater relative lip prominence in women is partly due to reduced nasal projection.
- Influences of ethnicity: Black individuals tend to have more prominent lips, due to greater soft tissue lip thickness and a tendency to bimaxillary dentoalveolar protrusion. There is also a tendency for reduced prominence of the nose and the chin compared with Caucasian populations.

S-line (Steiner): The S-line is drawn from the midpoint of the S-shaped curve between subnasale and pronasale to soft tissue pogonion.^{21,22}

- The lips should lie on this line
- If they lie behind this line the lips are retrusive, and if they lie in front of this line they are protrusive.

Z-line and Z-angle (Merrifield): The profile line of Merrifield, or Z-line, is drawn tangent to soft tissue pogonion and to the most prominent point of either the lower or upper lip, whichever is most prominent.²³ The angle formed by the intersection of this profile line and the Frankfort Horizontal plane (or ideally the true horizontal plane) is referred to as the Z-angle.

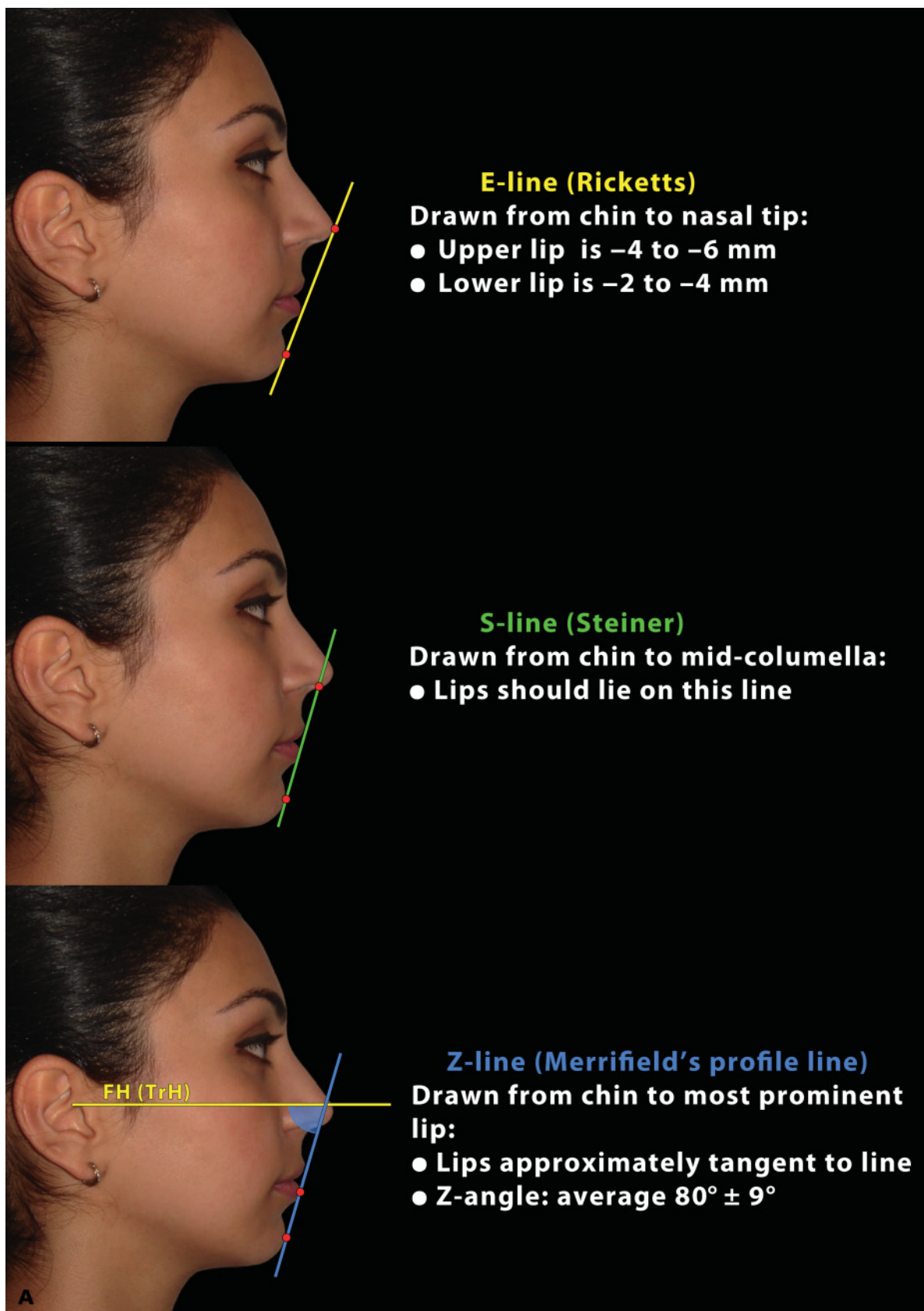


Figure 17.33 (A and B) Aesthetic analyses may be used to evaluate the relative prominence of the lips in relation to the facial profile, in particular to the nose and chin.

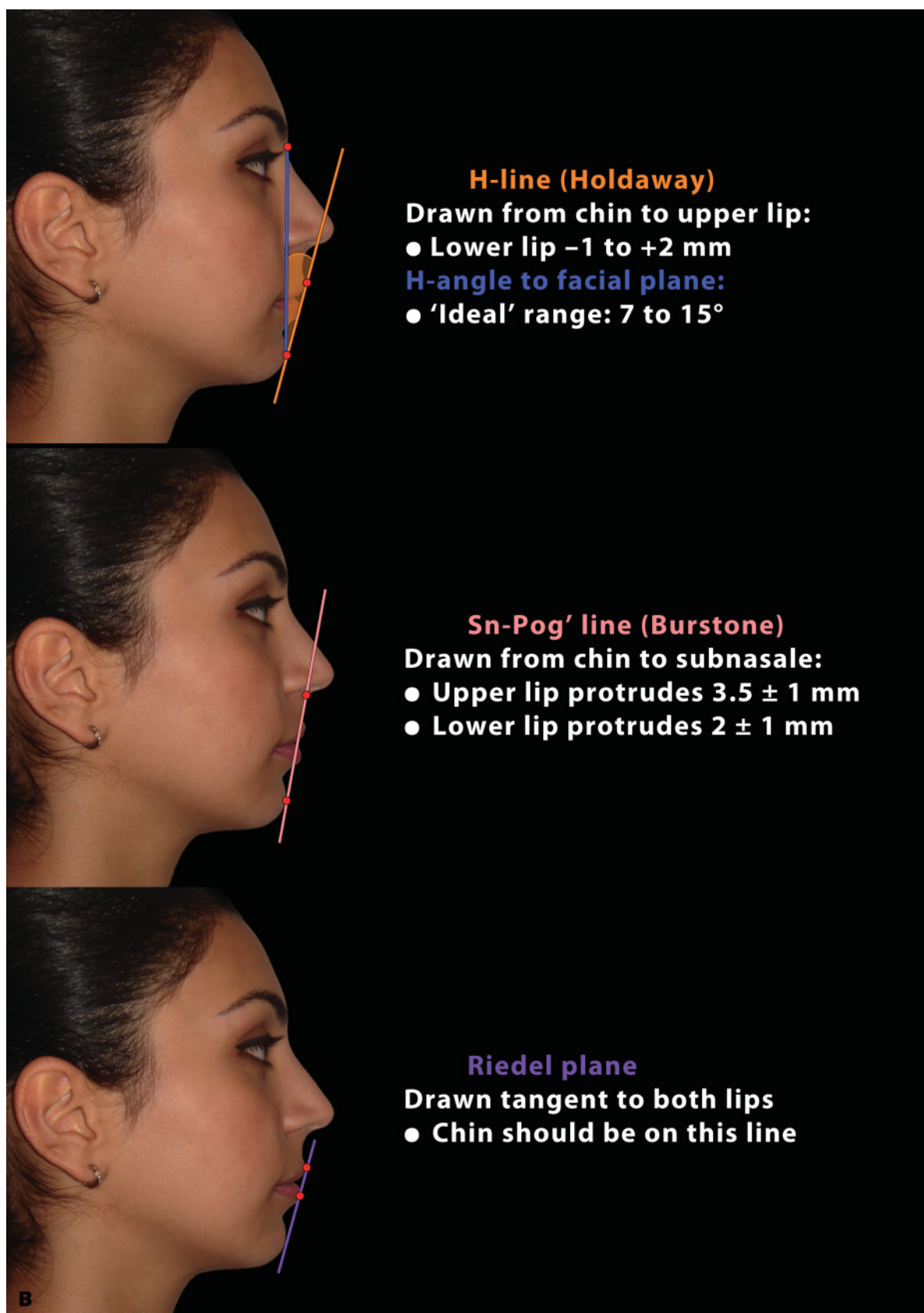


Figure 17.33 Continued

- Z-angle: average $80^\circ \pm 9^\circ$
- Upper lip (Ls) should be tangent to the profile line
- Lower lip (Li) should be tangent or slightly behind the profile line.

H-line and H-angle (Holdaway): The H-line (Harmony line) is drawn from soft tissue pogonion tangent to the upper lip.^{9,10}

- Labrale inferius of lower lip should be close to H-line, with a range of -1 to $+2$ mm.

The H-angle is the angle formed between the H-line and the *soft tissue* (N'-Pog') profile line. The H-angle measures the degree of upper lip prominence, assuming a normal chin prominence.

- H-angle 'ideal' range: $7-15^\circ$
- The H-angle will increase and decrease in proportion to the degree of facial convexity.

Note

The H-angle may also be formed by the intersection of the H-line and the *skeletal* nasion-B point line. This must be evaluated in conjunction with the ANB angle. If the ANB angle is increased or reduced from the average ($2-4^\circ$), the difference is correspondingly added to or subtracted from the H-angle for appropriate assessment of the lip and chin prominence.

Sn-Pog'-line (Burstone): Upper and lower lip prominence may be measured in relation to the subnasale-soft tissue pogonion (Sn-Pog') line. This will eliminate the nose from the analysis.¹³⁻¹⁵ The normal values for white Caucasians reported by Burstone were:

- Upper lip protrudes 3.5 ± 1 mm
- Lower lip protrudes 2 ± 1 mm.

Riedel plane: This relates the prominence of the lips to the chin (see Chapter 20). According to Riedel, the point of maximum chin projection should be on a line tangent to the upper and lower lips.²⁴

True vertical line through subnasale (SnV): The prominence of the upper lip may be related to a true vertical line passing through subnasale (subnasale vertical or SnV line).

- Labrale superius of upper lip should be 1–2 mm in front of SnV
- Labrale inferius of lower lip should be on or 1 mm behind SnV.

Note

Irrespective of the analysis employed, there is general agreement that the *lower lip should rest slightly posterior to the upper lip in profile view* (Figure 17.34).

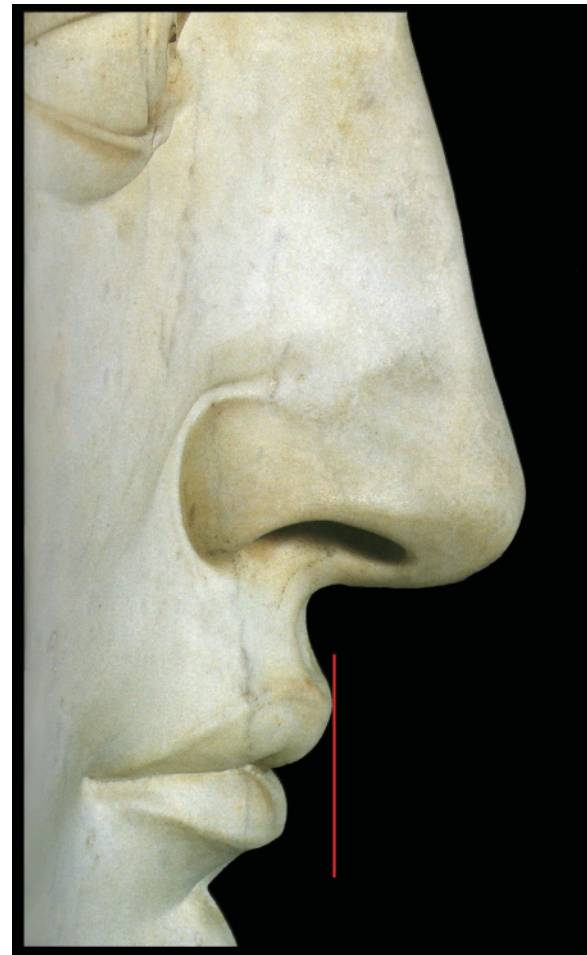


Figure 17.34 As a general guideline, the lower lip should rest slightly posterior to the upper lip in profile view. (Detail, *David*, c. 1501–4, Michelangelo Buonarroti, Gallerie dell'Accademia, Florence.)

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Chapter 18 Mentolabial (Labiomental) Fold

Introduction

The **mentolabial** (or **labiomental**) **fold** is also known as the **mentolabial sulcus**. It is a region that is evident in frontal and profile view, forming the *transition from the lower lip to the soft tissue chin*. In frontal view the visible indentation responsible for the separation of the lower lip from the chin is known as the **mentolabial groove** or **crease**. The morphology of the mentolabial region is one of the most important aesthetic parameters of the lower face (Figure 18.1).

Mentolabial fold (sulcus) depth

The depth of the mentolabial fold may be measured from the deepest point of the fold (sublabiale or soft tissue B-point) with a horizontal line that is perpendicular to a vertical line from labrale inferius (vermilion border of the lower lip) to soft tissue pogonion (Figure 18.2).

- Mentolabial fold depth:^{1,2} 4 ± 2 mm.

The mentolabial fold depth may be slightly greater in men (6 mm) than women (4 mm) due to the greater chin prominence.

Mentolabial angle

The mentolabial angle is the angle formed between the lower lip and soft tissue chin. The angle should be approximately 130° , but there is considerable individual variation (Figure 18.3):³

- Male: $115\text{--}145^\circ$.
- Female: $120\text{--}130^\circ$.

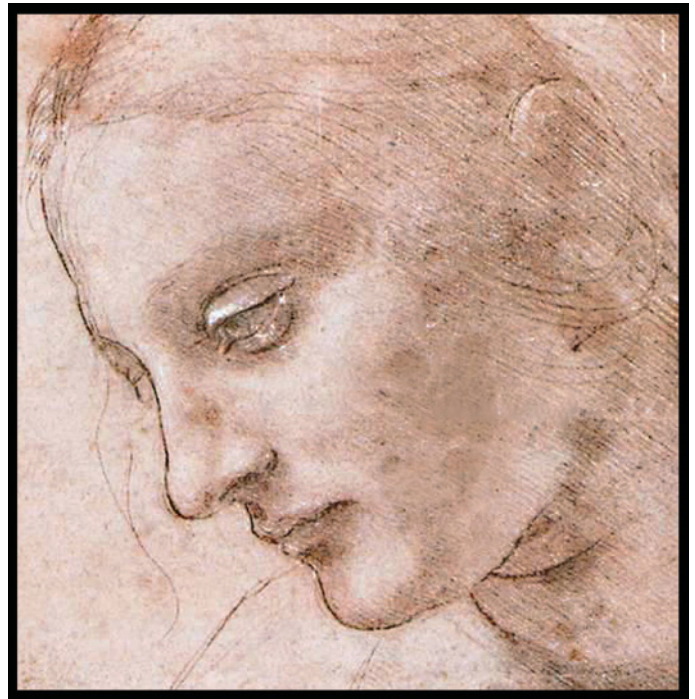


Figure 18.1 The morphology of the mentolabial region is an important aesthetic parameter of the lower face. (Detail, *Study of the Head of a Woman*, Leonardo da Vinci, c.1490, Musée du Louvre, Paris.)

Like most facial profile angles between two neighbouring structures, the mentolabial angle may be divided into its two component angles by a true horizontal line drawn through sublabiale:

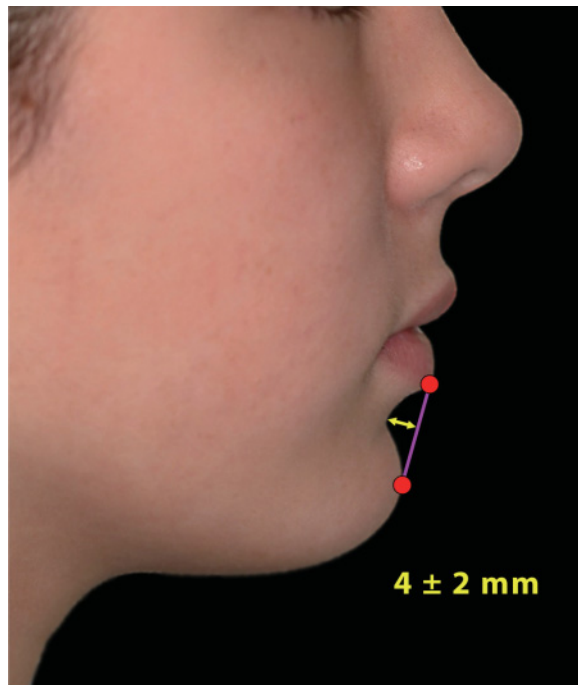


Figure 18.2 Mentolabial fold depth.

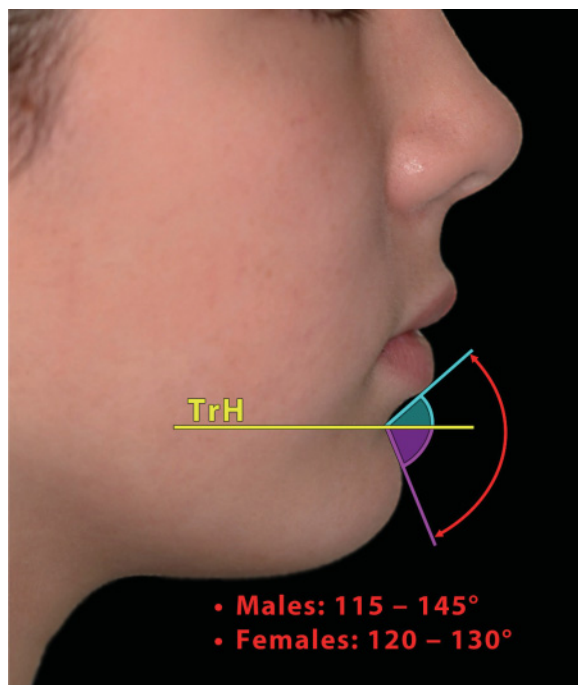


Figure 18.3 Mentolabial angle and its component parts. TrH, true horizontal plane.

- **Upper component:** This is the inclination of the lower lip in relation to the true horizontal line through sublabiale. It may be referred to as the **lower lip-to-mentolabial crease inclination**, or **lip-to-crease incline**.⁴ Normative values for this angle have been provided:³
 - Male: $47\text{--}50^\circ \pm 18^\circ$.
 - Female: $50^\circ \pm 14^\circ$.

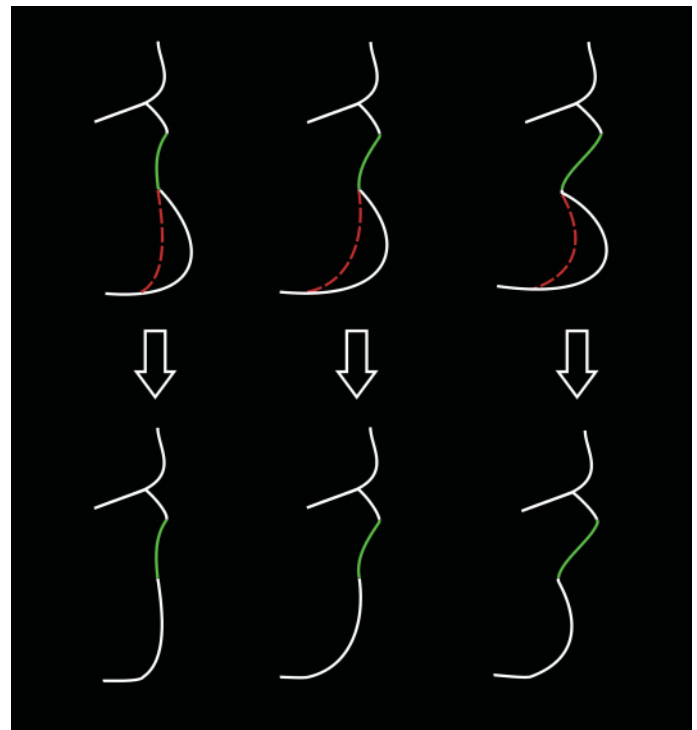


Figure 18.4 Variations in the inclination of the lower lip and corresponding results following horizontal reduction genioplasty. (Redrawn from Zide and Boutros⁴ with kind permission of Wolters Kluwer Health.)

- **Lower component:** This is the inclination of the soft tissue chin to the true horizontal line through sublabiale.

Note

Mentolabial angle (upper component) and macrogenia reduction: Zide and Boutros⁴ have described a crucial diagnostic point when deciding on the extent of reduction genioplasty in patients with horizontal macrogenia: the **upper component of the mentolabial angle**, i.e. the inclination of the line from the lower lip to the mentolabial groove/crease (**lower lip incline**); Zide refers to this as the **lip-to-crease incline**.

In profile view, *the same degree of horizontal macrogenia may present with a variable lip-to-crease inclination*. If the inclination is straight (vertical), horizontal reduction genioplasty will result in flattening and effacement of the mentolabial fold. Conversely, if there is a forward inclination of the lip-to-crease line, the same extent of reduction genioplasty will not efface the mentolabial fold (Figure 18.4). As a general guideline, the greater the forward inclination of the lip-to-crease line, the greater the leeway in horizontal reduction genioplasty.

The **mentolabial angle** depends on one or a combination of the following factors:

- **Soft tissue factors:**
 - **Morphology of the lower lip:** e.g. a flaccid, protrusive lower lip may reduce the mentolabial angle, whereas

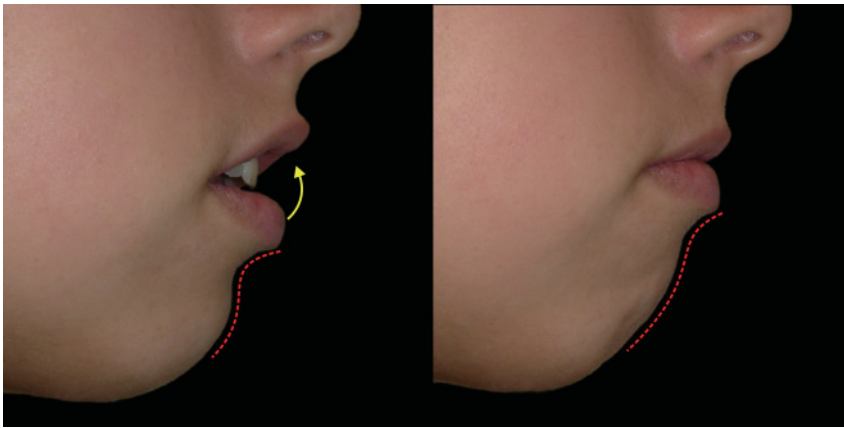


Figure 18.5 Patients with incompetent lip posture often elevate the lower lip in order to maintain a lip seal; this elevation, due to contraction of the mentalis muscle, tends to flatten the mentolabial fold.



Figure 18.6 Increased horizontal chin projection leads to a decrease in the mentolabial angle.

a thin, strap-like lower lip will tend to increase the angle.

- **Lower lip posture:** Patients with an incomplete lip seal (lip incompetence) have a tendency to elevate the lower lip in order to maintain a lip seal; this elevation, due to contraction of the mentalis muscle, tends to flatten the mentolabial fold (Figure 18.5).
- **Horizontal chin projection (due to increased thickness of soft tissue chin pad):** Increased horizontal chin projection leads to a decrease in the mentolabial angle and vice versa (Figure 18.6).
- **Skeletal factors:**
 - **Horizontal chin projection (skeletal horizontal macrogenia):** Increased horizontal chin projection leads to a decrease in the mentolabial angle and vice versa.
 - **Lower anterior face height (LAFH):** A reduction in LAFH may increase the mentolabial angle, deepening the mentolabial fold. Conversely, an increase in LAFH

may reduce the mentolabial angle and reduce or even completely remove the mentolabial fold (Figure 18.7). The impact of such changes on the **aesthetic contour** of this area must be accounted for in treatment planning.

Note

A deeper mentolabial fold may appear more attractive on patients with increased LAFH, as the presence of the fold tends to deemphasize the height of the lower face. Conversely, more shallow folds may appear more attractive in short face individuals as a deep fold would make the face appear even shorter.⁵

• Dentoalveolar factors:

- **Inclination of the mandibular incisors:** Proclined mandibular incisors will tend to protrude the lower lip; retroclination of the mandibular incisors may permit some retrusion of the lower lip, but this will depend to a great extent on the thickness and tonicity of the lower lip and the ability to achieve a competent lip posture.
- **Protrusion or retrusion of the mandibular dentoalveolus:** The effect is as described above.
- **Anatomy of alveolar B-point:** i.e. if skeletal B-point is set back, the mentolabial fold will tend to be deep and the angle reduced; if set forward in position, the mentolabial angle will tend to be increased.
- **Eversion of the lower lip by proclined maxillary incisors:** In Class II patients with proclined maxillary incisors and reduced lower anterior face height, the maxillary incisors may impinge on the lower lip causing its eversion (Figure 18.8).

Note

McBride and Bell⁶ pointed out that the mentolabial fold tends to deepen and the mentolabial angle reduces with advancement genioplasty, as the soft tissue chin pad advances with the underlying bony symphysis, whereas the lower lip and mentolabial fold remain behind.

Figure 18.7 Influence of lower anterior face height on mentolabial angle.

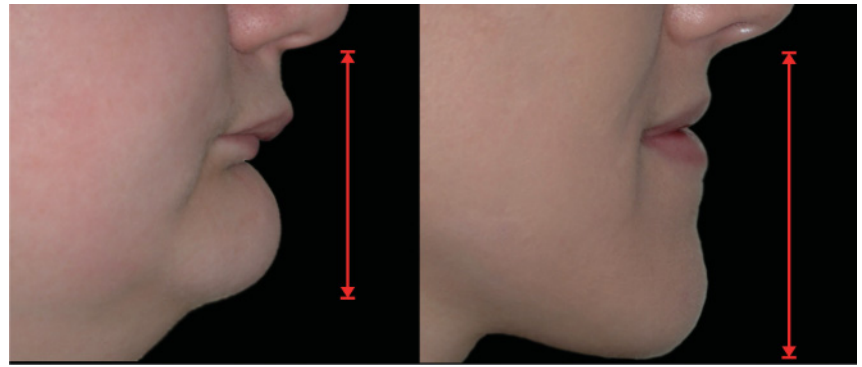


Figure 18.8 Eversion of the lower lip by proclined maxillary incisors in Class II patients with reduced lower anterior face height.

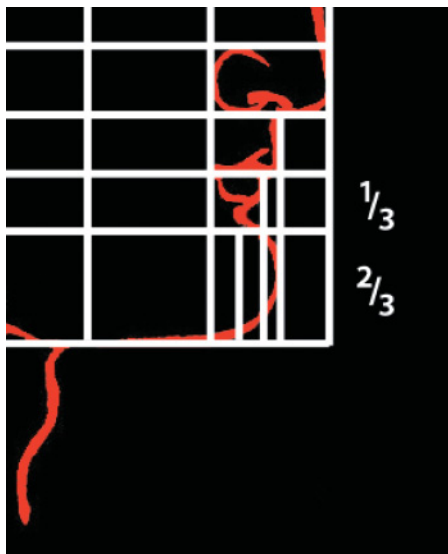
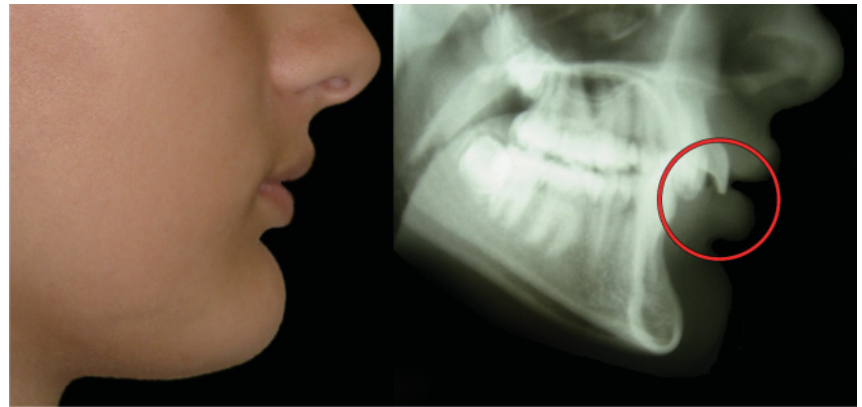


Figure 18.9 The vertical level of the deepest part of the mentolabial fold (redrawn from Dürer; see Figure 9.2).

Vertical position of the mentolabial fold

Michelow and Guyuron⁷ state that the deepest part of the mentolabial fold is located at the junction of the upper one-third to the lower two-thirds of the distance from the commissure to soft tissue menton. This agrees with the lower facial proportional canon described by Albrecht Dürer (Figure 18.9; see also Figure 9.2). However, Rosen⁵ found that there is no reliable reference

for determination of the normal depth or angle of the mentolabial fold, due to the *considerable individual variation*.

Mentolabial fold morphology

The morphology of the mentolabial fold is an important diagnostic criterion in treatment planning, particularly the correction of the Class II patient with mandibular deficiency. The 'ideal' management of such patients usually involves combined orthodontic-orthognathic surgery, involving orthodontic alignment, decompensation and dental arch coordination prior to mandibular advancement surgery.

Patients with chin deficiency secondary to mandibular deficiency, rather than isolated chin deficiency, may decide not to undergo combined orthodontic-orthognathic surgery due to the prolonged treatment time, but decide on camouflage advancement genioplasty. Nonetheless, it is important to understand the difference between the two procedures.

Advantages of mandibular advancement surgery over isolated genioplasty

The advantages of mandibular advancement surgery (Figure 18.10) over isolated genioplasty (Figure 18.11) are:

- **Lower lip position:** The often retrusive lower lip will advance together with the soft tissue chin.
- **Mentolabial angle:** The often acute mentolabial angle in short face, Class II patients will open and the mentolabial fold will 'soften'.

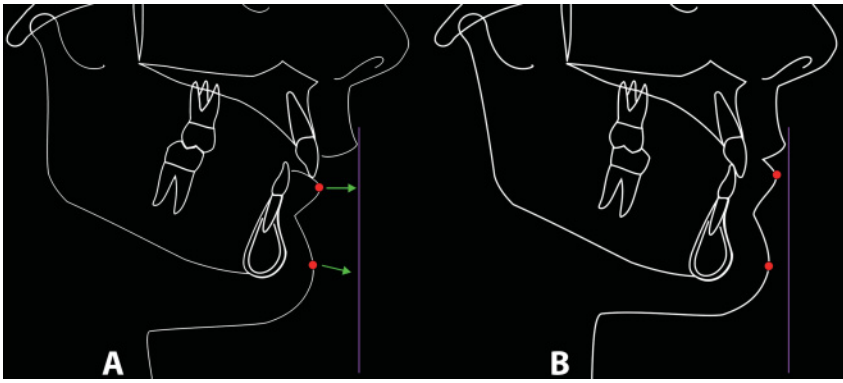


Figure 18.10 With mandibular advancement surgery the retrusive lower lip will advance together with the soft tissue chin; the mentolabial angle will open, particularly if the lower anterior face height is increased. The Class II dental occlusal relationship will also be corrected.

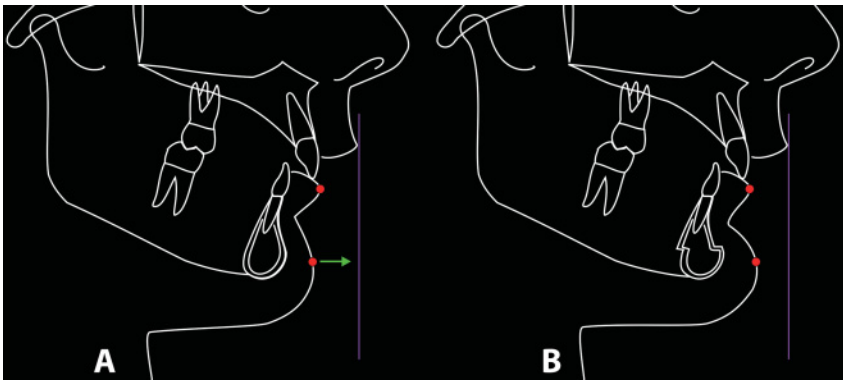


Figure 18.11 With isolated horizontal advancement genioplasty only, changes to the lower lip prominence and dental occlusion will not occur; the mentolabial fold tends to deepen and the mentolabial angle reduces as the soft tissue chin pad advances with the underlying bony symphysis, whereas the lower lip and mentolabial fold remain behind.

- **Lower anterior face height (LAFH):** The LAFH may be increased in patients with reduced LAFH, by maintaining a curve of Spee in the mandibular arch, surgically advancing the mandible to a three-point landing (interarch tooth contact at the incisors and terminal molars only) thereby increasing the LAFH, and then orthodontically closing the lateral open bites by orthodontic extrusion.
- **Dental occlusion:** The Class II dental occlusal relationship will be corrected.

Of these advantages, some changes in the mentolabial angle and LAFH are possible with isolated genioplasty, by altering the vector of bony chin movement (see below). However, *changes in lower lip prominence and the dental occlusion require mandibular advancement surgery.*

The following discussion involves patients who decide on isolated camouflage genioplasty to correct chin deficiency secondary to mandibular deficiency.

Influence of mentolabial fold morphology on management of chin deformities

The genioplasty (or mentoplasty), first described by Hofer in 1942,⁸ is an anterior horizontal osteotomy of the mandibular symphysis. It is one of the most versatile surgical procedures of the facial skeleton, able to alter the size and position of the bony chin in all three dimensions.

One of the most important considerations in clinical diagnosis and treatment planning of chin deformities is the soft tissue

morphology of the chin and, in particular, the mentolabial fold. Rosen⁵ has described, with characteristic clarity, the influence of different **vectors** (sagittal and vertical) and the **magnitude** of bony chin movement on mentolabial fold aesthetics, and therefore, how the accurate diagnosis of pre-existing fold morphology will influence the type of surgical procedure performed.

The depth of the mentolabial fold will generally increase as the symphysis is advanced in the sagittal dimension.⁶ However, alterations in the vertical chin height also have a significant influence on the mentolabial fold.⁵

Influence of vector of bony chin movement on mentolabial fold morphology

- **Sagittal advancement or simultaneous advancement and vertical shortening of symphysis:** Mentolabial fold appears deeper and better defined; mentolabial angle reduces (becomes more acute).
- **Simultaneous sagittal advancement and vertical increase in height of symphysis:** Reduces the apparent depth of the fold, opening the mentolabial angle; or, at least neutralizes the effect of isolated advancement, i.e. prevents the fold from becoming deeper.

Influence of lower anterior face height on mentolabial fold morphology

The underlying skeletal deformity responsible for patients' perception of chin deficiency is usually a small mandible

Table 18.1 Influence of lower anterior face height (LAFH) on labiomental fold morphology in ‘Class II’ patients with mandibular deficiency and reduced chin projection

Mentolabial fold morphology	Class II dentofacial deformity due to mandibular deficiency			
	Decreased LAFH	Normal LAFH	Increased LAFH (VME, reduced ramus height, posterior mandibular rotation, obtuse gonial angle and/or increased vertical chin height) (Figure 18.12A)	Increased LAFH (increased posterior face height, increased ramus height, less obtuse or even acute gonial angle and/or increased overbite) (Figure 18.12B)
Depth of fold	Excessively deep (due to lower lip eversion and procumbency, secondary to mandibular overclosure)	Considerable variability (depends on extent of sagittal mandibular deficiency and incisor relationship)	Attenuated, shallow, flattened, effaced fold	Deep, exaggerated fold
Definition of fold	Well defined	Variable	Poorly defined	Well defined
Mentolabial angle (between lower lip and soft tissue chin pad)	Acute (reduced angle)	Variable	Obtuse (increased angle)	Often acute
Lip posture	Competent – if normal incisor relationship Potentially competent – if interposed maxillary incisors due to increased overjet and deep overbite		Incomplete lip seal (lip incompetence) – lip strain evident	Lip strain may be evident
Lip prominence	Lips compressed together; protruded lower lip or bilabial protrusion (variable, depending on lip thickness)			
Mentalis muscle			Hypertrophy; elevated soft tissue chin pad (corrugated appearance of chin; ‘bunching’ of muscle)	
Influence on patient management (patients refusing combined orthodontic-orthognathic surgical correction)	Genioplasty: Advance and vertically increase height (simultaneous increase in height prevents further fold deepening, and/or reduces <i>apparent</i> * fold depth; reduces apparent lip prominence and improves lip posture)	Variable: Mentolabial fold morphology will help determine vector and magnitude of chin movement required (i.e. necessity for simultaneous alteration of chin height with sagittal advancement [†])	Genioplasty: Advance and vertically shorten (mentolabial fold will <i>appear</i> * deeper and better defined; closes mentolabial angle; improves lip posture)	<i>Avoid genioplasty</i> ; may use clockwise bimaxillary rotation

*The *relative* depth of the mentolabial fold is more important than the actual depth. The mentolabial fold may actually be deeper after the chin is advanced and increased in height but will *appear* less deep because the mentolabial angle is less acute (described as ‘softening’ of the fold). Therefore, the *perception* of fold depth and the definition of the mentolabial region are more important than absolute values.⁵

[†]In Class II, mandibular deficient patients with normal LAFH, the mentolabial fold morphology helps determine the vector and magnitude of chin movement:

- Shallow mentolabial fold: Isolated sagittal advancement genioplasty is indicated in order to increase the apparent depth and definition of the fold.
- Normal or increased mentolabial fold depth: It may be preferable to advance and modestly increase the height of the chin. The slight increase in LAFH may be preferable to the deepening of the mentolabial fold with isolated sagittal chin advancement.⁵

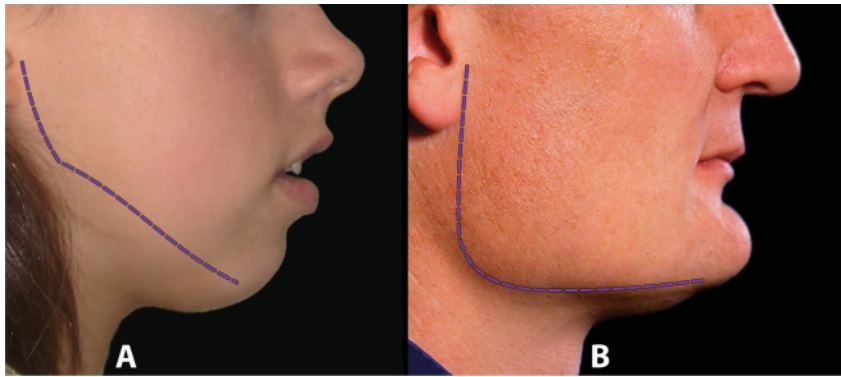


Figure 18.12 (A) Increased lower anterior face height (LAFH) due to posterior vertical maxillary excess, reduced ramus height, posterior mandibular rotation, obtuse gonial angle and increased vertical chin height; advancement and vertically shortening genioplasty will reduce the mentolabial angle and improve lip posture. (B) Increased LAFH with increased posterior face height, increased ramus height, anterior mandibular rotation, acute gonial angle and increased incisor overbite; avoid genioplasty and use clockwise bimaxillary rotation to rotate chin down and back, reducing chin prominence and opening the mentolabial fold.

(mandibular micrognathia), not a small chin (microgenia). The variability in facial morphology in such 'Class II' patients is primarily due to the variation in the LAFH (Table 18.1 and Figure 18.12).⁵

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Chapter 19 The Mandible

Terminology

See 'terminology' section in Chapter 16.

Anatomy, morphology and size

Normal anatomy and subunits

The mandible, the bone of the lower jaw, is one of the most important bones in the craniofacial complex; its anatomy and structural relationships are thus highly significant (Figure 19.1). For descriptive purposes, the mandible may be said to be comprised of a number of subunits: the two main parts are the **ramus**, which is for articulation and the insertion of jaw-moving muscles, and the **body (corpus)**, which carries the dentition (Figure 19.2). The body is horseshoe-shaped when viewed from above, and the two vertical rami project upwards one from each posterior end of the body. The posterior border of the ramus projects upwards as the **condylar process**, which consists of a neck, expanding into a condylar head or **condyle**. The body of the mandible projects up around the teeth as **alveolar bone**, which forms the walls of the tooth sockets. After loss of a tooth the living alveolar bone atrophies. Extensive tooth loss may thereby lead to a reduction in lower anterior face height due to loss of the **dentoalveolar process** (Figure 19.3). The **inferior border** of the mandible provides the demarcation between the lower face and neck. The anterior extremity of the mandibular body is the highly variable prominence of the **mandibular** or **mental symphysis (bony chin)**.

Morphology

Typical morphology: The morphology of the mandible (*excluding* the bony chin) is relatively consistent, depending on the basic type of dentofacial deformity with which a patient may present, e.g. 'Class II', 'Class III', 'short face' or 'tall face'. Conversely, the morphology of the bony chin is highly variable and will be described in detail in Chapter 20.

Gonial angle (Ar-Go-Me): This is a measure of the angle formed between the slope of the posterior border of the mandibular ramus and the mandibular plane. It helps to describe the morphology of the mandible, in particular the relationship between the ramus and the body (Figure 19.4). It is highly correlated with the mandibular plane angle.

- Riolo et al. (USA, 1974)¹ described normal values:
 - Male: $124^{\circ} \pm 6^{\circ}$
 - Female: $122^{\circ} \pm 4^{\circ}$.
- Bhatia and Leighton (UK, 1993)² described normal values:
 - Male: $126^{\circ} \pm 6^{\circ}$
 - Female: $128^{\circ} \pm 5^{\circ}$.

An increased gonial angle is associated with **posterior mandibular growth rotation**, and a reduced gonial angle is associated with **anterior mandibular growth rotation**. In order to determine the relative contribution of the ramus and body of the mandible to mandibular morphology, the gonial angle may be divided into two parts, an upper and lower component, by drawing a **facial depth line** (nasion-gonion). The upper



Figure 19.1 (A) Oblique right lateral view. (B) Superior view. (C) Oblique left posterior view.

- | | | |
|----|-------------------------------------|--------------------|
| 1 | Condylar head | } Condylar process |
| 2 | Condylar neck | |
| 3 | Pterygoid fovea | |
| 4 | Coronoid process | |
| 5 | Ramus | |
| 6 | Oblique line | |
| 7 | Gonial angle | |
| 8 | Alveolar process | |
| 9 | Body (corpus) | |
| 10 | Mental foramen | |
| 11 | Inferior border | |
| 12 | Mental protuberance | |
| 13 | Mandibular foramen | |
| 14 | Superior and inferior mental spines | |
| 15 | Sigmoid (mandibular) notch | |

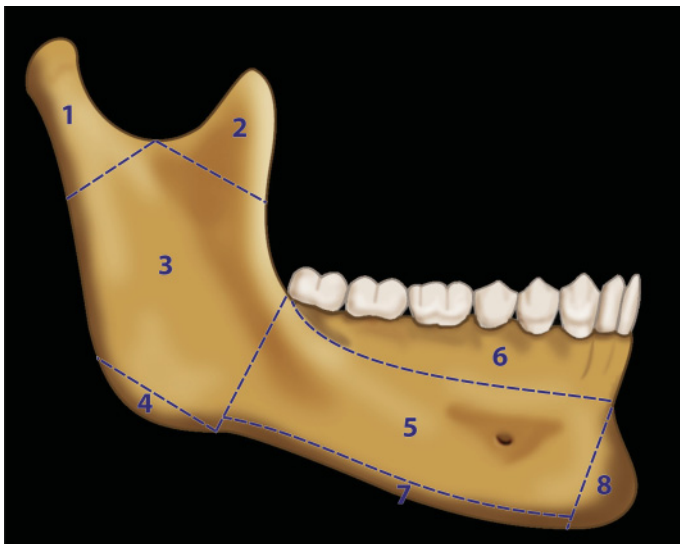


Figure 19.2 Mandibular subunits:

- 1 Condylar subunit
- 2 Coronoid subunit
- 3 Ramus
- 4 Gonial angle
- 5 Body (corpus)
- 6 Dentoalveolus (dentoalveolar subunit)
- 7 Inferior border
- 8 Mandibular symphysis (bony chin subunit)

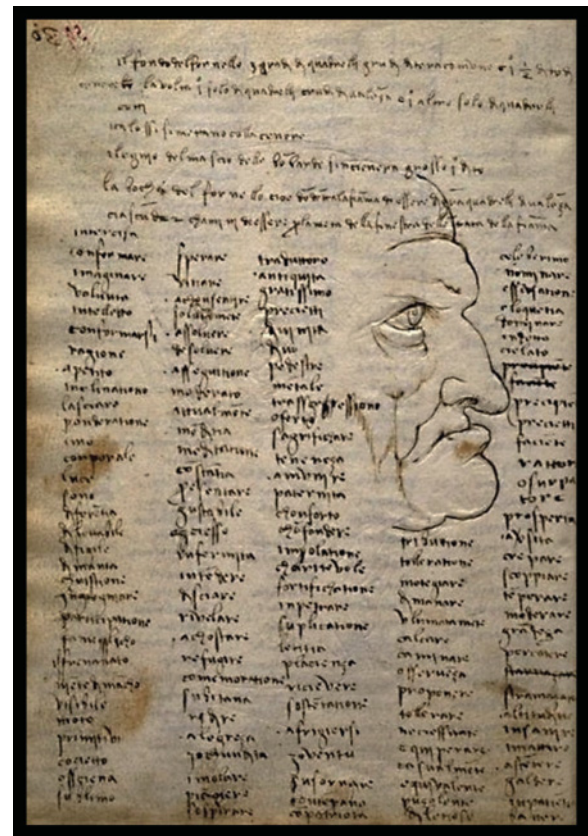


Figure 19.3 Extensive tooth loss results in resorption of the alveolar process and thereby a reduction in the lower anterior face height; the mandible will rotate anteriorly bringing the chin characteristically closer to the nose. (*Head of an Old Man*, c. 1487–90, Leonardo da Vinci, Codex Trivulzianus, Sforza Castle, Milan.)



Figure 19.4 (A) Reduced, acute gonial angle. (B) Increased, obtuse gonial angle.

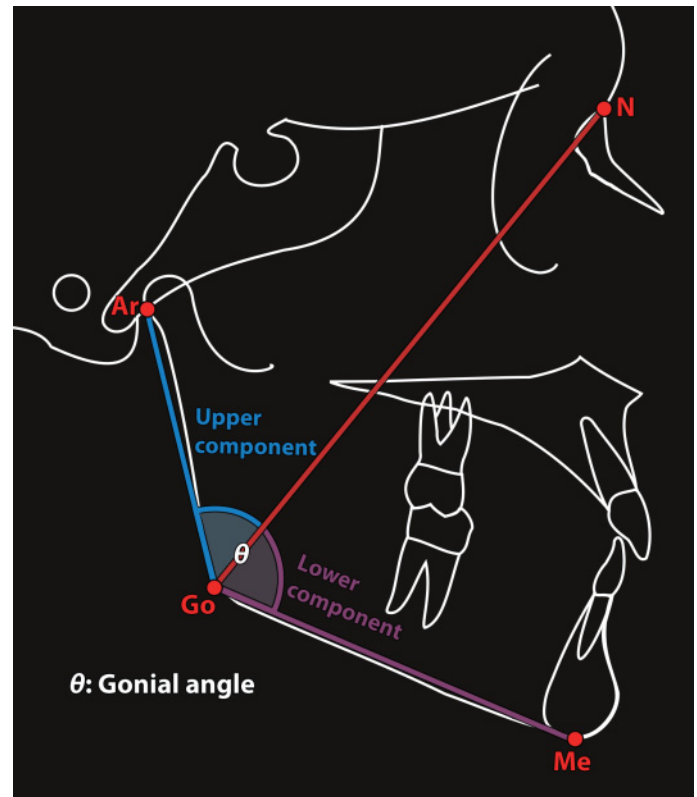


Figure 19.5 The gonial angle may be divided into an upper and lower component in order to determine the relative contribution of the ramus and body inclination to mandibular morphology.

component of the gonial angle ($50^\circ \pm 2^\circ$) identifies the inclination of the ramus and the lower component identifies the inclination of the body of the mandible (Figure 19.5).³

Mandibular growth rotations: Growth rotations of the mandible occur when there is a discrepancy in the amount of anterior and posterior lower facial heights. It is important to bear in mind that the amount of rotation is masked to some extent by periosteal remodelling and dentoalveolar adaptation. **Forward (anterior) rotation** of the mandible, in the direction of mouth closing, is due to increased posterior vertical facial growth relative to anterior vertical facial growth (Figure 19.6A). **Backward (posterior) rotation** of the mandible, in the direction of mouth opening, is due to reduced posterior vertical facial growth relative to anterior vertical facial growth (Figure 19.6B). Björk⁴ described **seven structural signs** found on a lateral cephalometric radiograph, which may provide an indication to the pattern of mandibular growth (Table 19.1 and Figure 19.7).

Inferior border of the mandibular body: The lower border of the mandible should be well defined, providing *distinct separation of the lower face from the neck*. This region will be relatively unattractive in the absence of such demarcation between the lower face and neck, which may be due to skeletal and/or soft tissue factors (Figure 19.8):

- **Skeletal factors:**
 - Increased gonial angle

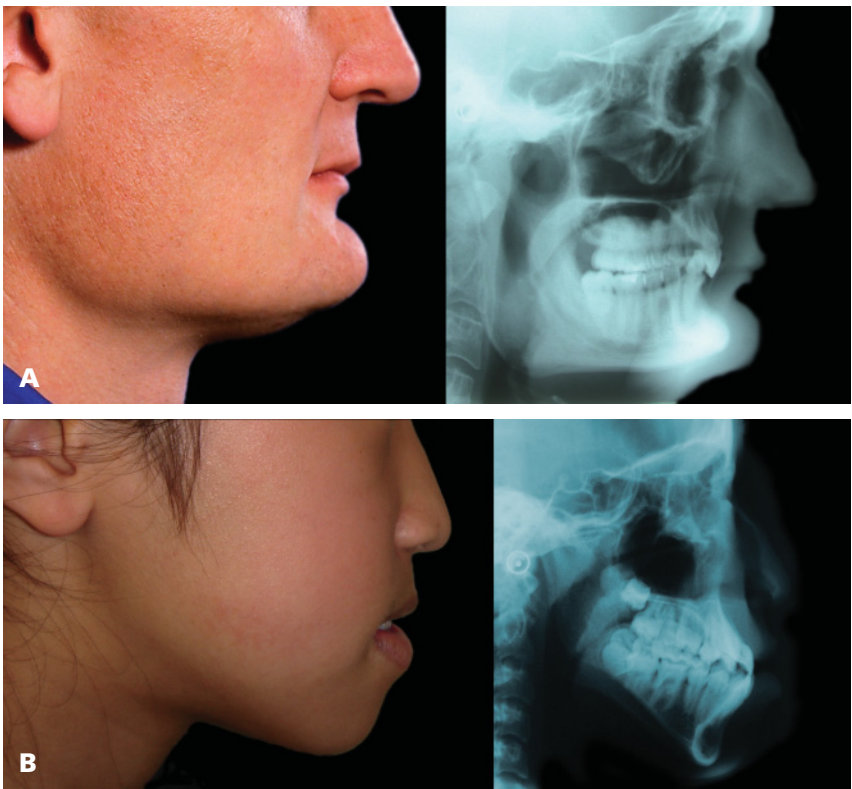


Figure 19.6 (A) Forward (anterior, anticlockwise) rotation of the mandible, in the direction of mouth closing, is due to increased posterior vertical facial growth relative to anterior vertical facial growth. (B) Backward (posterior, clockwise) rotation of the mandible, in the direction of mouth opening, is due to reduced posterior vertical facial growth relative to anterior vertical facial growth.

Table 19.1 Björk's seven structural signs indicating the pattern of mandibular growth rotation

	Structural signs	Forward (anterior) mandibular growth rotation	Backward (posterior) mandibular growth rotation
1	Inclination of the condylar head	Forward	Backward
2	Curvature of the mandibular canal	Increased curvature	Straight canal
3	Shape of the lower border of the mandible	Absence of an antegonial notch	Convex lower border and antegonial notch
4	Inclination of the mandibular symphysis (bony chin)	Forward inclination, increased chin projection	Backward inclination, reduced chin projection
5	Interincisal angle	Increased	Reduced
6	Intermolar and interpremolar angle	Increased	Reduced
7	Lower anterior face height	Reduced	Increased

For the numbers, refer to Figure 19.7.

- Increased mandibular plane angle
- Reduced mandibular body length.
- **Soft tissue factors:**
 - Increased cervical facial adiposity
 - Redundant lower facial soft tissues/jowling.
- Any combination of the above.

A thorough clinical evaluation of this region is required, involving clinical inspection and palpation. The lateral cephalometric radiograph, orthopantomograph (OPT) and where

necessary three-dimensional reconstruction of the mandible permits more accurate analysis of the inferior mandibular border. When skeletal and soft tissue factors coexist, surgical correction to redefine the natural demarcation in this region may involve augmentation of the lower mandibular border and gonial angles in conjunction with rhytidectomy.

Size and position

- **Absolute size:** Normal values for mandibular dimensions in white Caucasians have been provided by Bhatia and Leighton² and Riolo et al.¹ (Table 19.2 and Figure 19.9).

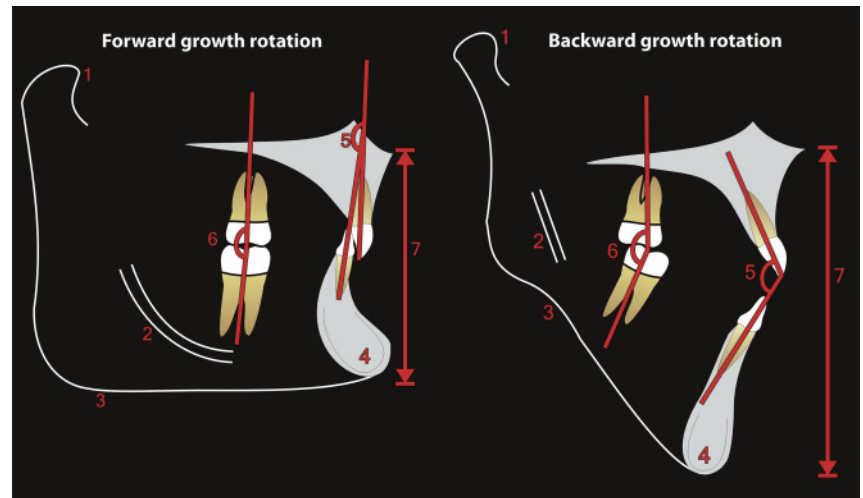


Figure 19.7 Björk's seven structural signs, which may be used to indicate the pattern of mandibular growth (for an explanation of the numbers, refer to Table 19.1).



Figure 19.8 Indistinct inferior border of the mandible.

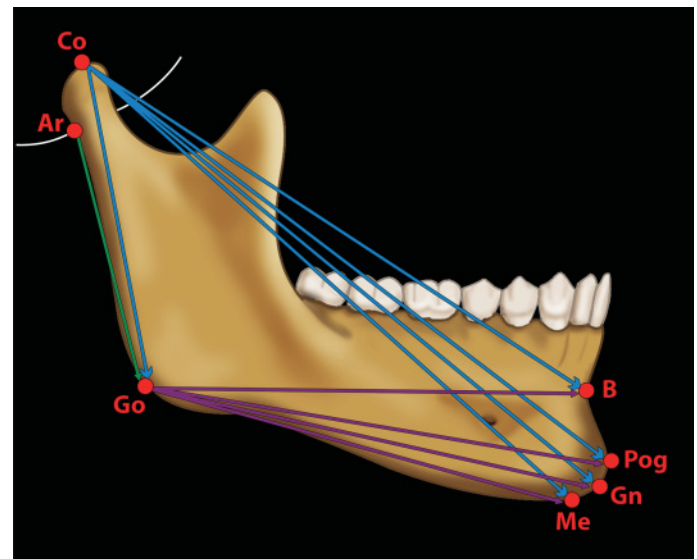


Figure 19.9 Mandibular dimensions (for normative values see Table 19.2).

Note

For adolescent 'Class II' patients, one of the most valuable indicators of the requirement for surgery is a reduced mandibular *body* length (gonion-pogonion) of less than 70 mm (US male norm: 87 ± 4 mm).⁵ This equates to a reduction in mandibular body length of 80%.

- **Relative position:** The sagittal position of the mandible may be analysed in relation to the anterior cranial base, the facial vertical (or nasion perpendicular) or the sagittal position of the maxilla:
 - **Anterior cranial base (SN)** (see Figure 7.22):
 - **SNB:** $79^\circ \pm 3^\circ$
 - **SN-Pog:** $80^\circ \pm 3^\circ$
 - **SND:** $76-77^\circ$.
 - **Nasion perpendicular** (see Figure 7.14):
 - B-point is 2–3 mm behind N-perpendicular.

• Maxilla:

- **ANB** (see Figure 7.24): $3^\circ \pm 1^\circ$.

Proportional relationship of body to ramus

Mandibular micrognathia (a small mandible) may have reasonable proportionality between the ramus and body. Although hypoplasia of the mandible may affect the ramus, body or both, *syndromic* mandibular deficiency is often due to a short mandibular ramus. The surgical technique of distraction osteogenesis may be used to differentially lengthen the ramus and/or the body of the mandible. The craniofacial dimensions of patients with craniofacial syndromes in particular may not fit into normal ranges of variability. Therefore, the use of **proportional analysis** rather than comparison with population 'norms' is a useful method of evaluating the specific area (ramus or body), direction and extent of lengthening that may be required.

Table 19.2 Normal mandibular dimensions (white Caucasian adults)

Parameter	Normal value (mm)			
	UK norms (Bhatia and Leighton, 1993) ²		US norms (Riolo et al., 1974) ¹	
	Male	Female	Male	Female
<i>Total mandibular length</i>				
Condylion-B point	103 ± 4	97 ± 3	117 ± 5	110 ± 4
Condylion-pogonion	116 ± 5	108 ± 4	131 ± 6	121 ± 4
Condylion-gnathion	119 ± 5	110 ± 4	134 ± 5	124 ± 4
Condylion-menton	117 ± 5	108 ± 4	130 ± 5	122 ± 4
<i>Body length</i>				
Gonion-B point	71 ± 5	66 ± 3	80 ± 4	77 ± 4
Gonion-pogonion	78 ± 4	71 ± 4	87 ± 4	82 ± 4
Gonion-gnathion	78 ± 4	71 ± 4	86 ± 4	81 ± 4
Gonion-menton	75 ± 4	68 ± 4	81 ± 4	78 ± 3
<i>Ramus height</i>				
Condylion-gonion	59 ± 4	55 ± 4	66 ± 4	61 ± 2
Articulare-gonion	48 ± 4	44 ± 4	54 ± 4	50 ± 4

Refer to Figure 19.9.

- Ratio of ramus height (Co-Go): mandibular body length (Go-Gn) is 5:7.
- Ratio of maxillary length (ANS-PNS): mandibular body length (Go-Gn) is 2:3.
- Ratio of anterior cranial base length (SN) to mandibular body length (Go-Gn) is approximately 1:1.

Sagittal and vertical relationships

Mandibular deficiency

The **characteristic feature** of sagittal mandibular deficiency, and the most common complaint from the 'Class II' patient, is the *retruded position of the chin* relative to the rest of the face in profile view. It is important to distinguish *true* skeletal mandibular deficiency from *relative* mandibular deficiency.

True sagittal mandibular deficiency

True sagittal mandibular deficiency may be due to:

- A small mandible (**mandibular micrognathia**).
- A repositioned mandible (**mandibular retrognathism**).
- A combination of the above.

Relative mandibular deficiency

Relative mandibular deficiency may be due to:

- **Horizontal microgenia**: It is important to bear in mind that the deformity may be localized to the chin, with an

otherwise normal mandible. The morphology of the chin is highly variable and is discussed in Chapter 20.

- **Posterior mandibular rotation** (downward and backward, in the direction of mouth opening): Secondary to vertical maxillary excess.
- **Maxillary and/or midfacial prognathism**: The mandible may be in a normal sagittal position, but will *appear* deficient as the maxilla is prognathic.
- Any combination of the above.

The aetiology of mandibular deficiency may include a combination of relative and true mandibular deficiency.

Note

It is not uncommon for patients with mandibular deficiency to present with an element of maxillary deficiency in the sagittal plane. In such patients treatment may involve bimaxillary advancement surgery.

Diagnostic features

The diagnostic features of sagittal mandibular deficiency depend to a great extent on the lower anterior facial height (LAFH). In patients with sagittal mandibular deficiency and a *normal* or *reduced* LAFH, the diagnostic features are (Figure 19.10):

- **Chin position**: The chin is repositioned in the sagittal plane relative to the rest of the face in profile view. The chin itself may have normal morphology, but it will appear retro-positioned due to a small or repositioned mandible. If the

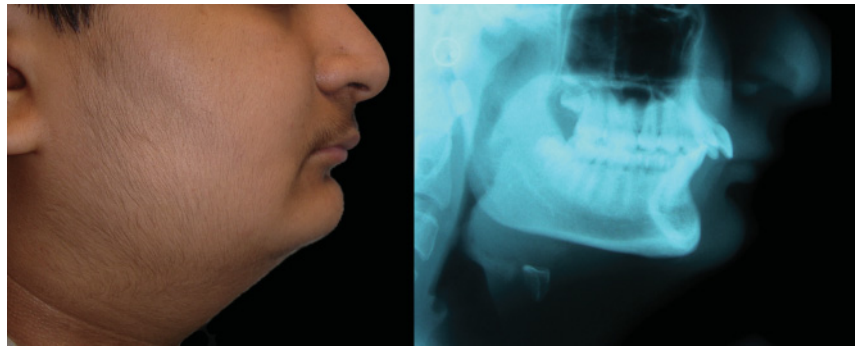


Figure 19.10 Sagittal mandibular deficiency with a reduced lower anterior facial height.

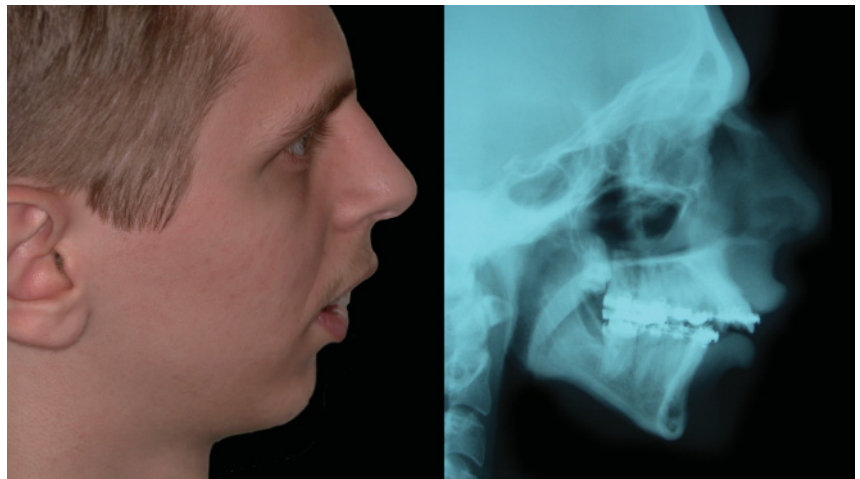


Figure 19.11 Sagittal mandibular deficiency with an increased lower anterior facial height.

chin is well developed in the sagittal plane (normogonia or horizontal macrogonia), it may reduce the Class II appearance of the facial profile. Conversely and less commonly, if the chin is underdeveloped in the sagittal plane (horizontal microgonia) as well as mandibular deficiency, the Class II appearance will be more pronounced.

- **Lower lip position:** The lower lip is retropositioned in the sagittal plane relative to the rest of the face in profile view. This is *perhaps the most important diagnostic feature*, as it distinguishes the Class II profile due to horizontal microgonia (isolated small chin), where the lower lip relationship will be normal to the rest of the face, with that due to horizontal mandibular deficiency, where the lower lip is retropositioned.
- **Lower lip morphology:** The lower lip is commonly *everted*, particularly in Class II division 1 incisor relationship, when the lower lip is caught behind the maxillary incisors leading to their proclination. The proclined maxillary incisors are interposed between the lips and in turn will evert the lower lip. This tendency is accentuated as the lower anterior face height reduces.
- **Mentolabial fold:** This tends to be accentuated, with a reduced, acute mentolabial angle, particularly when the lower anterior facial height is markedly reduced.

- **Gonial angles:** These tend to be reduced, giving a square appearance to the mandibular angles. It is not uncommon to have hypertrophy of the masseter muscles.
- **Intraoral features:** The incisor overjet tends to be increased, although the mandibular incisors may be proclined as a result of *dentoalveolar compensation* for the underlying Class II skeletal pattern. Proclined mandibular incisors may in turn lead to a degree of protrusion of the lower lip. The maxillary incisors are often proclined due to the lower lip being trapped behind them. The incisor overbite tends to be increased, with an increased curve of Spee due to over-erupted mandibular incisor teeth.

In patients with sagittal mandibular deficiency and an *increased LAFH*, the diagnostic features are (Figure 19.11):

- **Chin position:** Excessive LAFH is often accompanied by **posterior vertical maxillary excess** (posterior VME), i.e. there is inferior rotation of the posterior maxilla and vertical downward movement of the associated posterior maxillary dentition. Secondary to posterior VME, the mandible rotates posteriorly (downwards and backwards, in the direction of mouth opening), thereby *moving the chin downwards and backwards*. This rotation will make the patient 'more Class II', the severity depending on the original sagittal mandibular



Figure 19.12 The prominent 'Hapsburg jaw' and protrusive lower lip of the Hapsburg dynasty is evident in the portraits of (A) Charles V, Holy Roman Emperor (1500–58) and (B) Charles II of Spain (1661–1700).

problem. A 'tall face' patient may be described as skeletal Class I rotated to Class II (or as skeletal Class III rotated to Class I).

- **Lip morphology and posture:** One of the most significant clinical signs of excess LAFH is *excessive separation of the lips at rest*, termed an **incomplete lip seal** (or **lip incompetence**). Proffit⁶ has stated that lips held *habitually apart by more than 4 mm in repose* may be considered the outer limit of normal. In the Class II patient with mandibular retrognathia, the upper lip has a tendency to be short and hypoplastic. This is likely to be due to lack of function, as the patient will form an anterior oral seal by elevating the lower lip behind the maxillary incisors and contacting the protruding tongue. Correction of the underlying skeletal deformity will permit normal lip function, which may allow the upper lip to develop normally.
- **Mentolabial fold:** This tends to be flat, with an increased mentolabial angle.
- **Gonial angles:** These tend to be increased, due to the posterior mandibular growth rotation.
- **Intraoral features:** With posterior rotation of the mandible, the mandibular incisors will often retrocline, possibly due to pressure from the lower lip. As the anterior face height increases the tendency for the maxillary and mandibular incisors will be to separate in the vertical plane. If the incisor eruption is capable of compensating for the excess face height, the overbite may remain within normal limits; otherwise an **anterior open bite** may occur.

Mandibular excess

The aetiology of Class III jaw deformity, in particular mandibular excess, has a very strong genetic basis.⁷ The familial tendency of Class III deformity may be frequently observed in members

of the same family. A famous example is of the Hapsburg dynasty, one of the German royal families. Over 23 generations portrait painters have captured images of the Hapsburgs, and they all exhibit the same mandibular prognathism and protrusive lower lip, often termed the 'Hapsburg jaw' (Figure 19.12). In addition, evidence from twin studies has suggested the strongest genetic predisposition for Class III malocclusion, with concordance in identical twins six times higher than in non-identical twins for mandibular prognathism.⁸ Although there is a strong familial occurrence, there seems to be no association with sex, with different modes of transmission in different families or populations.⁹

Edward Angle, described as the father of modern orthodontics, recognized early in the twentieth century that severe mandibular excess could only be corrected through a combination of orthodontics and mandibular surgery (Figure 19.13).¹⁰

The **characteristic feature** of mandibular excess, and the most common complaint from the 'Class III' patient, is the *prominence of the chin and lower lip* relative to the rest of the face in profile view (Figure 19.14). It is important to distinguish *true* skeletal mandibular excess from *relative* mandibular excess.

True mandibular excess

True sagittal skeletal mandibular excess may be due to:

- A large mandible (**mandibular macrognathia**).
- An excessively forward positioned mandible (**mandibular prognathism**).
- A combination of the above.

Relative mandibular excess

True skeletal mandibular excess must be distinguished from relative (apparent) mandibular excess. Conditions in which the mandible *appears* excessively prominent are:

- **Horizontal macrogenia** (osseous and/or soft tissue): The chin is unusually large and prominent on an otherwise normal mandible.
- **Maxillary and/or midfacial hypoplasia:** The mandible may be in a normal sagittal position, but will *appear* prominent as the maxilla is retrognathic. This is a very common finding in patients with operated cleft lip and palate.
- **Anterior rotation of the mandible** (upward and forward, in the direction of mouth closing): This condition is often secondary to maxillary hypoplasia and vertical maxillary deficiency (VMD), as the mandible rotates forward excessively (overclosure) around the condylar hinge axis (Figure 19.15).
- **Anterior mandibular displacement:** In the presence of a mild Class III incisor relationship, patients with an uncomfortable edge-to-edge incisor occlusion may displace and posture the mandible anteriorly in order to achieve maximum intercuspation of the posterior teeth (Figure 19.16).
- Any combination of the above.

The aetiology of mandibular excess often results from a combination of relative and true mandibular excess.

Note

The term 'prognathism' means positioned 'too far forward'. Nevertheless, in clinical practice, the term 'mandibular prognathism' is used synonymously with sagittal 'mandibular excess', i.e. whether the sagittal 'mandibular excess' is due to excessive size of the mandible (mandibular macrognathia) or excessive forward position of a normal sized mandible, both may be referred to as 'mandibular prognathism'. It is also important to bear in mind that an excessively large mandible may not be 'too far forward' in the sagittal plane if there has been significant posterior rotation of the mandible, i.e. macrognathia without prognathism.

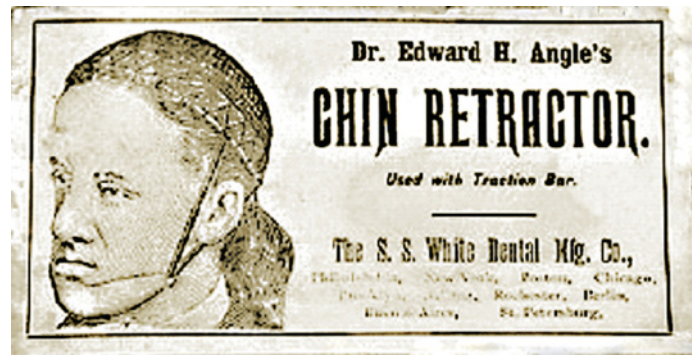


Figure 19.13 The 'chin retractor' of Edward Angle was a predecessor to the chin cup (chin cap) used by orthodontists in the attempt to correct mandibular excess in young patients by restraining mandibular condylar growth; Angle later recognized the limitations of such appliances.

Diagnostic features

The patient is examined in natural head position. In frontal view, the patient with true mandibular excess exhibits increased breadth of the lower two-thirds of the lower facial third, and distinct overdevelopment of the lower jaw (Figure 19.17). The prominence of the lower jaw will be even more apparent in profile view.

The relationship of the chin and lower lip to the upper lip, midface, nose and forehead may be evaluated by 'masking' the lower jaw and lower lip and evaluating the relationship of the other structures. This may be undertaken clinically by holding a piece of card over the lower part of the lower facial third; alternatively it can be undertaken on the clinical profile photograph.



Figure 19.14 The characteristic feature of mandibular excess is the prominence of the chin and lower lip relative to the rest of the face in profile view. The two contrasting heads demonstrate an attractive profile (left panel) and a 'Class III' profile with mandibular excess and protrusive lower lip (right panel). (Michelangelo, c. 1516–24, The Ashmolean Museum, Oxford.)



Figure 19.15 Excessive forward rotation of the mandible (overclosure), secondary to mild maxillary hypoplasia and loss of the posterior dentition.



Figure 19.16 Anterior mandibular displacement: patients with an uncomfortable edge-to-edge incisor occlusion (A) may displace and posture the mandible anteriorly in order to achieve maximum intercuspation of the posterior teeth (B); the mandible/chin and lower lip thereby protrude.



Figure 19.17 In frontal view, the patient with true mandibular excess exhibits increased breadth of the lower two-thirds of the lower facial third and distinct overdevelopment of the lower jaw.

This is important as a large mandible may make a normal midface seem deficient (Figure 19.18).

The diagnostic features of mandibular excess are:

- **Chin position:** The prominence of the chin is the most characteristic feature observed in profile view (Figure 19.19). However, it is not uncommon for a patient with a large and prognathic mandible to have a small chin (microgenia). In such patients, mandibular setback surgery may lead to sagittal chin deficiency. This may necessitate an advancement genioplasty, particularly in men, in order to avoid subsequent lack of chin projection.
- **Lower lip position:** The lower lip will tend to be protrusive, depending in extent on the degree of mandibular excess (Figure 19.20). However, dentoalveolar compensation and the resultant retroclination of the lower incisors lead to a less protrusive position of the lower lip. Orthodontic decompensation and proclination of the lower incisors prior to mandibular setback surgery will increase the protrusion of the lower lip, and patients must be warned of this temporary change (Figure 19.21).

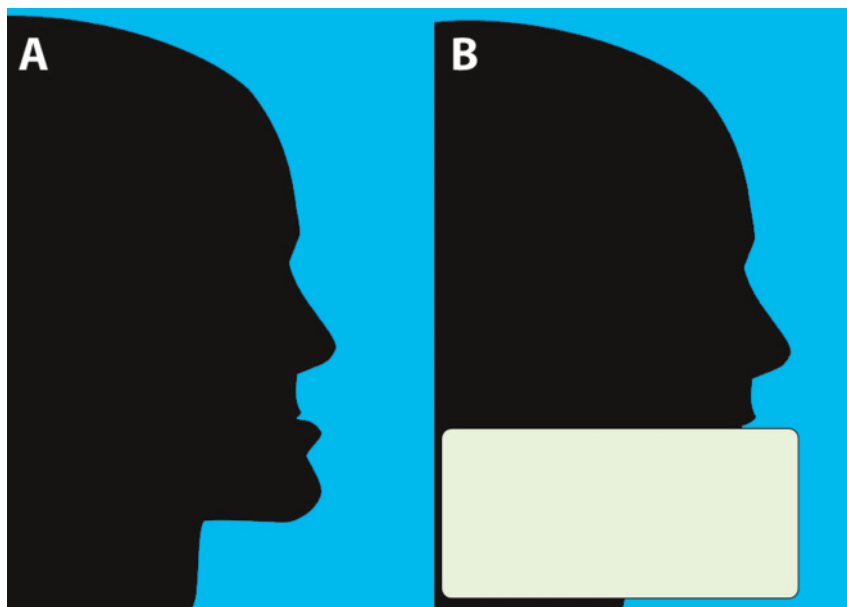


Figure 19.18 (A) Mandibular excess may create the illusion of upper lip and/or maxillary deficiency. (B) Masking the lower lip and chin demonstrates a normal upper lip prominence.



Figure 19.19 Chin prominence is usually the most characteristic feature observed in profile view in mandibular excess.



Figure 19.20 (A) Protrusive lower lip resulting from mandibular excess and maxillary deficiency. (B) Bimaxillary surgery (maxillary advancement and mandibular setback) has improved lower lip prominence.



Figure 19.21 (A) Class III jaw relationship – compensatory retroclination of mandibular incisors has limited the prominence of the lower lip. (B) Orthodontic decompensation by proclination of the mandibular incisors, in preparation for mandibular setback surgery, has increased the protrusion of the lower lip.



Figure 19.22 (A and B) Shortening of the mandibular body will reduce the submental length and tend to increase the submental-neck angle.

- **Lower lip morphology and posture:** An incomplete lip seal (lip incompetence) is common, and depends on the severity of the sagittal skeletal deformity and the vertical face height.
- **Influence of mandibular rotation and face height:** A reduction in mandibular face height due to anterior mandibular rotation will increase the prominence of the chin, whereas posterior mandibular rotation reduces chin prominence.
- **Mentolabial fold:** This is usually relatively flat.
- **Gonial angles:** These are variable, depending to a great extent on the direction of mandibular rotation. Posterior mandibular rotation is often correlated with increased, obtuse gonial angles.
- **Submental region:** The length of the submental region depends on the length of the mandibular body and the horizontal projection of the chin. This, together with the morphology of the submental soft tissues, will be affected by mandibular surgery. Shortening of the mandibular body will reduce the submental length and reduce the demarcation between the submental region and the anterior aspect of the

neck, with a tendency to increase the submental-neck angle, which may be unattractive (Figure 19.22).

- **Intraoral features:** Dentoalveolar compensation for the underlying Class III skeletal pattern results in proclination of the maxillary incisors and retroclination of the mandibular incisors (Figure 19.23). The magnitude of the reverse dental overjet depends on the severity of the jaw deformity and the extent of sagittal dentoalveolar compensation. Any increase in the lower anterior face height may result in the development of an anterior open bite if the vertical eruption of the incisor teeth cannot compensate for the increased face height. The maxillary dental arch tends to be relatively narrow and the mandibular dental arch wide often resulting in posterior dental crossbite, leading to problems with arch coordination.

Transverse relationships

Proportional relationships

- **Rule of fifths:** According to the rule of fifths, the 'ideal' face may be transversely divided into five equal parts, each



Figure 19.23 Dentoalveolar compensation for an underlying Class III jaw relationship results in proclination of the maxillary incisors and retroclination of the mandibular incisors.



Figure 19.24 Increased bigonial width.

roughly equal to one eye width. Bigonial width should fall within the medial fifths of the face. Increased bigonial width may occur in patients with increased skeletal bigonial width, or in patients with masseter muscle hypertrophy (Figure 19.24). In such cases the gonial angles will be lateral to the outer border of the medial fifth of the face.

- **Masseteric hypertrophy:** This is the enlargement of the masseter muscle insertions bilaterally leading to a distinctive widening of the skeletal and soft tissue bigonial width. The

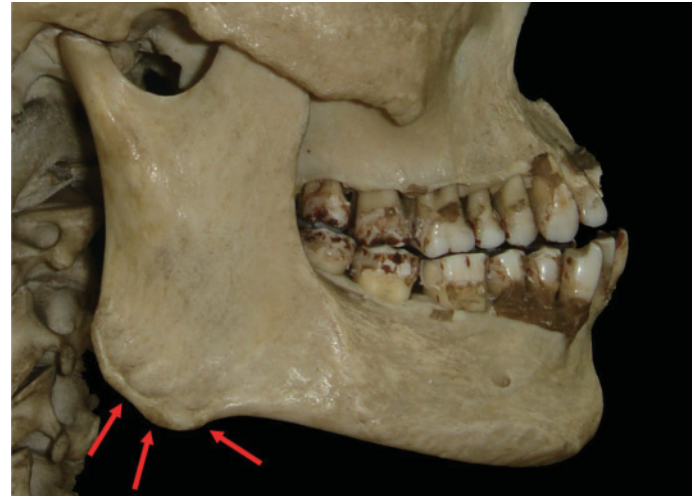


Figure 19.25 Masseteric hypertrophy leads to bone proliferation at the gonial angles with a characteristic change in morphology, in response to the increased mass and activity of the masseter muscle insertions.

gonial angles of the mandible are the sites of attachment of the masseter muscles laterally and the medial pterygoid muscles medially. Therefore, the morphology of this region depends to a great extent on the size, development and activity of these muscles. In bilateral masseteric hypertrophy bone proliferates at the gonial angles leading to a characteristic change in morphology, in response to the increased mass and activity of the masseter muscle insertions (Figure 19.25). In contrast, patients with muscular dystrophy have very underdeveloped gonial angles. These situations illustrate the importance of the muscle attachments in the development of the muscular processes and thereby in the morphology of the mandible.

Bicondylar width and bigonial width

- Bicondylar width:¹¹
 - Male: 102 ± 7 mm
 - Female: 98 ± 7 mm.
- Bigonial width (skeletal):¹¹
 - Male: 96 ± 7 mm
 - Female: 90 ± 7 mm.
- Bigonial width (soft tissue):¹¹
 - Male: 106 ± 7 mm
 - Female: 98 ± 7 mm.

Mandibular asymmetries

The diagnosis of facial asymmetry has been described in Chapter 10. Generalized disturbances of facial growth may affect the growth of the mandible, sometimes leading to facial asymmetry.

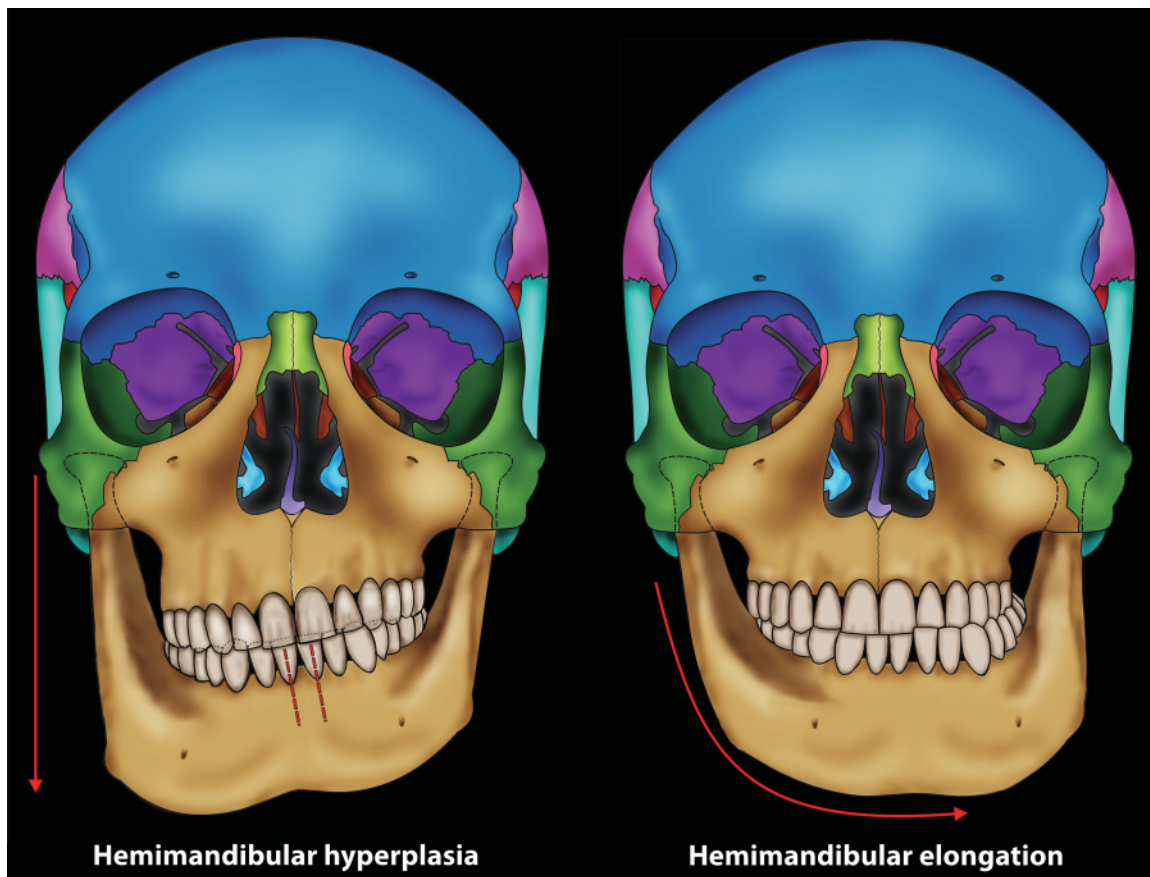


Figure 19.26 Hemimandibular hyperplasia and hemimandibular elongation.

However, significant facial asymmetry may result from *localized* aberrant growth patterns of the mandible itself. It is important clinically to distinguish true asymmetrical mandibular excess from *relative* excess, which may result from unilateral inhibition or arrest of growth. In such cases, the normal side will *appear larger* due to lack of growth on the affected side; examples include unilateral temporomandibular joint trauma in childhood resulting in retarded ipsilateral growth. Pathological conditions leading to mandibular asymmetry must also be ruled out, e.g. unilateral fibrous dysplasia.

The uncertain aetiology of asymmetrical mandibular excess led to the description of a number of classifications based on clinical observation, until a classic article by Obwegeser and Makek¹² classified mandibular asymmetry into three general groups:

- Hemimandibular hyperplasia (HH).
- Hemimandibular elongation (HE).
- Hybrid (mixed) forms of HH and HE.

To these may be added a further group resulting from isolated unilateral hyperplasia of a condyle occurring after cessation of normal craniofacial growth:

- Unilateral condylar hyperplasia.

Note

The aetiology of such developmental mandibular asymmetries is unknown. However, Obwegeser and Makek¹² reason that the steering mechanism for the growth of these anomalies is located entirely within the cartilaginous zone of the condylar head. This hypothesis is supported by the fact that in rapidly developing cases, the abnormal growth ceases after a high condylar resection has been performed.

The Obwegeser classification defines three forms of **condylar hyperactivity**, only two of which produce condylar hyperplasia; pure HE does *not* produce condylar hyperplasia.

Asymmetry of the lower third of the face resulting from excessive asymmetric growth of the mandible may be predominantly vertical in direction (**hemimandibular hyperplasia**), predominantly horizontal (**hemimandibular elongation**), or a combination of the two (Figure 19.26).

Hemimandibular hyperplasia

In HH, the entire affected side of the mandible and condyle are enlarged; this **three-dimensional hemimandibular enlargement** terminates exactly at the midline of the mandibular

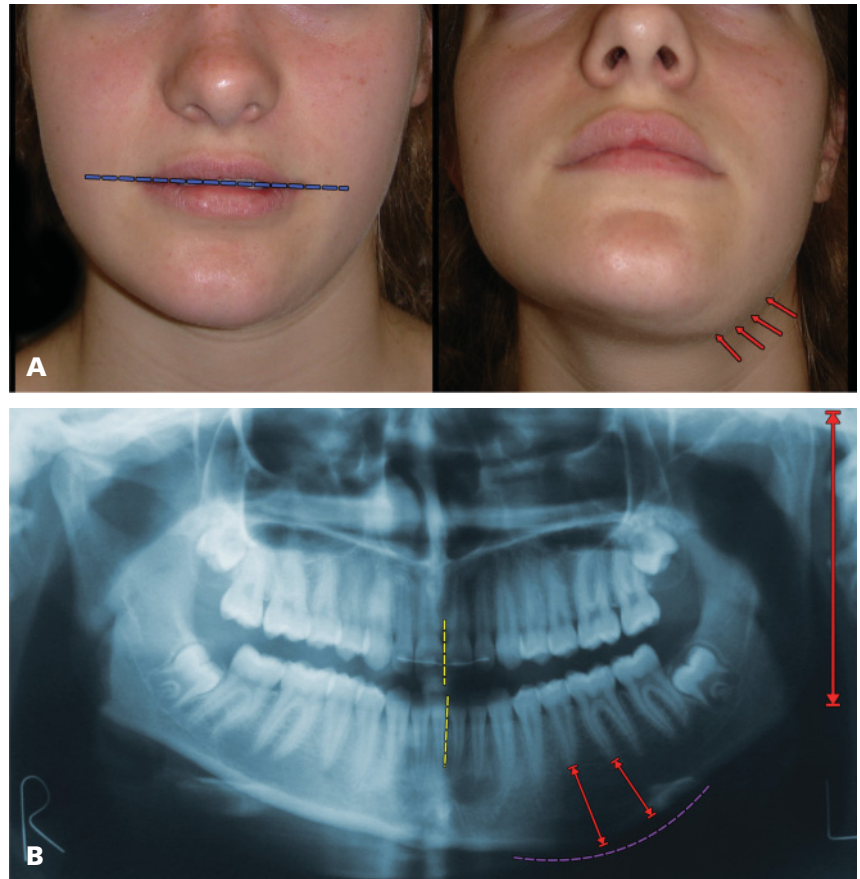


Figure 19.27 (A and B) Hemimandibular hyperplasia (patient's left side): The excessive asymmetrical growth is predominantly in a vertical direction. Vertical ramus height is increased and the inferior border bows excessively downward on the affected side. The inferior alveolar canal bows down close to the inferiorly bowed mandibular lower border. The body of the mandible on the affected side has increased bone height. The dental midlines tend to remain coincident. The chin may be almost in the midline of the face, but with a transverse cant of the inferior chin plane, lower on the affected side. The unilateral increase in lower face height gives rise to a sloping rima oris; the oral commissure on the affected side is displaced inferiorly but not laterally.

symphysis (Figures 19.27). The excessive asymmetrical growth is predominantly in a *vertical direction*. The vertical ramus height is increased and the inferior border *bows* excessively downward. The inferior alveolar canal bows down close to the inferiorly bowed mandibular lower border; the faster the asymmetry develops the closer to the mandibular lower border is the inferior alveolar canal. The body of the mandible on the affected side has increased bone height, i.e. the distance between the tooth root apices and the inferior mandibular border is increased. The dental midlines tend to remain coincident, but the mandibular incisors are excessively angulated towards the affected side.

The mandibular occlusal plane is oriented downward on the affected side (Figure 19.28), with compensatory overeruption of the maxillary dentoalveolus leading to a transverse cant of the maxillary occlusal plane. There is no posterior crossbite. There may be a lateral open bite on the affected side depending on whether the extent of maxillary dentoalveolar compensation on the affected side has kept up with the increased vertical ramal growth, and whether or not the tongue has found a resting position between the posterior dental occlusion. The chin may be almost in the midline of the face, but with a transverse cant of the inferior chin plane, lower on the affected side. The unilateral increase in lower face height gives rise to a sloping rima oris (Latin *rima*: 'a fissure'; Latin *oris*: 'mouth'); the oral commissure on the affected side is displaced inferiorly but not laterally. In severe cases the unilateral skeletal changes result in a typical 'corkscrew-like' rotation of the lower face.



Figure 19.28 The mandibular occlusal plane is oriented downward on the affected side.

Hemimandibular elongation

This hemimandibular growth anomaly differs entirely, both clinically and radiographically, from hemimandibular hyperplasia. The condyles are of equal size and are clinically and



Figure 19.29 (A and B) Hemimandibular elongation (patient's right side): The mandibular body on the affected side is longer, with the excessive asymmetrical growth predominantly in a *horizontal direction*. The mandibular dental midline and chin move to the unaffected side and a posterior dental crossbite results on the unaffected side. The mandibular incisor angulations are normal. The orientation of the transverse occlusal plane tends to remain normal. There is no height difference between the two sides of the face. There is no cant to the rima oris, but the lower lip tends to be displaced horizontally to the unaffected side.



Figure 19.30 (A) Combined hemimandibular hyperplasia and elongation (patient's left side). (B) Maxillary occlusal plane cant.

radiographically of *normal size*, but the affected side of the mandible is elongated, due to *unilateral condylar hyperactivity*. The mandibular body on the affected side is longer, with the excessive asymmetrical growth predominantly in a *horizontal direction*. The mandibular dental midline and chin move to the unaffected side and a posterior dental crossbite results on the unaffected side (Figure 19.29). The mandibular incisor angulations are normal. The orientation of the transverse occlusal plane tends to remain normal. There is no height difference between the two sides of the face. There is no cant to the rima oris, but the lower lip tends to be displaced horizontally to the unaffected side.

Hybrid (mixed) forms of hemimandibular hyperplasia and elongation

A combination of excessive hemimandibular mass (HH) and length (HE) production due to unilateral condylar hyperactivity gives rise to the hybrid forms of hemimandibular hyperplasia and elongation. One type dominates the clinical picture, i.e. the principal features will be either predominantly HH-type or HE-type. Hybrid forms must have clear features of both anomalies: a unilateral posterior crossbite on the unaffected side and chin deviation to the unaffected side (features of HE), and a vertical increase in the ramus height of the affected hemimandible, inferior bowing of the lower border of the mandible on the affected side and a transverse cant to the maxillary occlusal plane (features of HH) (Figure 19.30).

Unilateral condylar hyperplasia

The affected condyle is markedly larger in size and the length of the ipsilateral condylar neck is increased, leading to deviation of the mandible to the opposite side. However, the overall contour of the deviated mandible is symmetrical. There is little dentoalveolar compensation. The size and morphology of the contralateral condyle and condylar neck are essentially normal. It appears that the excessive condylar growth has initiated *after* completion of mandibular growth.

Note

Any of these forms of mandibular asymmetry may present in combination with sagittal skeletal discrepancies.

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Chapter 20 The Chin

Introduction

‘Thou whose features clearly beaming make the moon
of Beauty bright,
Thou whose chin contains a well-pit which to
Loveliness gives light.’
Hafez (1325–90)
Persian poet-philosopher¹

The chin is unique to humans. The human face as we know it originated with the *Homo sapiens* in Africa, approximately 130 000 years ago. Even Neanderthals retained a modest muzzle, whereas the need for a projecting mouth all but disappeared in modern humans. This flattening of the face and retrusion of the orodental complex coincided with the appearance and projection of the bony chin, perhaps a remnant of the now obsolete muzzle (Figure 20.1).

The morphology of the chin has a substantial influence on the perceived attractiveness of the face. In profile view, in particular, the chin establishes much of the character of the lower face (Figure 20.2). In fact, the prominence of the chin is one of the facial characteristics that society tends to associate with an individual’s personality. Individuals, particularly men, with a deficient chin may be viewed as ‘weak,’ whereas a prominent chin is often described as a ‘strong’ chin, implying strength of personality.

The authentic history of aesthetic chin surgery has been described by Wolfe (1987).² **Otto Hofer** (1942) is likely to have been the first surgeon to propose a horizontal osteotomy of the

mandibular symphysis and sliding advancement of the inferior fragment.³ The procedure was performed from an external approach and the ‘patient’ seems to have been a cadaver. The first report of aesthetic chin surgery in a living patient seems to be that of **Sir Harold Gillies** and **Ralph Millard Jr** (1957).⁴ The procedure was performed through an external approach, with the inferior fragment being advanced and positioned superiorly, anterior to the upper mandibular fragment; this procedure is now termed a ‘jumping genioplasty.’ **Richard Trauner** and **Hugo Obwegeser** (1957) later reported aesthetic chin surgery through an intraoral approach, and coined the term ‘genioplasty.’⁵ **John Converse** and **Donald Wood-Smith** (1964) reported their results through an intraoral approach, referring to the procedure as a ‘horizontal osteotomy of the mandible.’⁶ **Thomas Hohl** and **Bruce Epker** (1976) discussed vertical reduction of chin height by wedge osteotomy.⁷ **Kevin McBride** and **William Bell** (1980) discussed increasing the height of the chin with autogenous interpositional bone graft.⁸

Anatomy

Anatomically the chin is the area below the mentolabial fold, although separating the chin from the lower lip in patients with a poorly defined mentolabial fold can be difficult, particularly in frontal view. The anatomy, morphology and aesthetics of the lower lip, mentolabial fold and chin are intimately related. The chin consists of the bony anterior projection of the mandible, called the mandibular or mental symphysis, and its overlying soft tissue **chin pad**.

Figure 20.1 (A) Cranoskeletal morphology of *Homo erectus*, a species of hominid (of the human family) that walked upright and lived more than one million years ago. (With kind permission, © Natural History Museum, London.) (B) Cranoskeletal morphology of modern human (modern *Homo sapiens*) demonstrates the differences between the two species: *Homo sapiens* has a larger cranium, a taller forehead, reduced prominence of the brow ridge, reduced mandibular length, reduced bimaxillary protrusion, smaller teeth and a pronounced bony chin.

Image not available in the electronic edition



Figure 20.2 The chin establishes much of the character of the lower face, particularly in profile view. (Detail, *Study for the Face of Leda*, Michelangelo, c. 1530, Casa Buonarroti, Florence.)

Note

Alternative terms for the bony chin are **mandibular symphysis**, **mental symphysis** or **mental protuberance**.

Terminology

The ability to accurately describe and thereby classify facial deformities is essential, and a prerequisite to correct diagnosis, leading to correct treatment planning. An important step towards classification is therefore to define the clinical terminol-

ogy based on etymology. *The terminology used should reflect the underlying aetiology.*

- Genio- (Greek *geneoin*: chin).
- Mento- (Latin *mentum*: chin).
- Pogo-, pogono- (Greek: beard).
- Macro- (Greek *macros*: large or abnormally large).
- Micro- (Greek *micros*: small or abnormally small).
- Pro- (prefix Greek, Latin: forward).
- Retro- (prefix Latin: backward or behind in position).

Chin excess and chin deficiency

The terms 'chin excess' and 'chin deficiency' may be used to describe chin deformities in the sagittal or vertical plane.

Progenia (sagittal chin excess)

Progenia is a term used to indicate that the *sagittal position* of soft tissue pogonion (Pog', the most prominent point on the soft tissue contour of the chin, in the midsagittal plane) is protrusive (too far forward) in relation to the rest of the craniofacial complex. This may be due to a relatively larger size (macrogenia) and/or a more anterior position of the chin.

Progenia is a non-specific term describing the sagittal position of the chin, not the underlying aetiology. Progenia may be classified as primary, secondary or 'relative'.

Primary progenia (primary sagittal chin excess): This is a *structural* problem, describing a *morphological* deformity of the chin area. An alternative and preferred term is 'sagittal chin excess'. The aetiology of sagittal chin excess may be due to one or a combination of the following:

- Horizontal osseous macrogenia (Figure 20.3B)
- Increased thickness of soft tissue chin pad (Figure 20.3C)
- Any combination of the above.

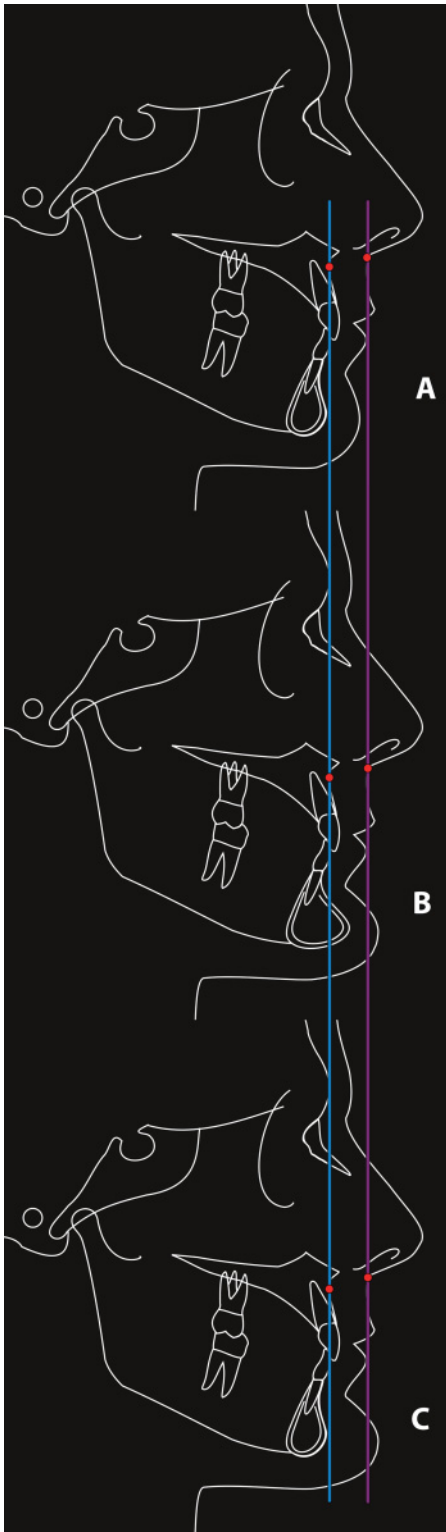


Figure 20.3 (A) Normal chin prominence. (B) Horizontal osseous macrogenia, (C) increased thickness of soft tissue chin pad.

Secondary progenia (secondary sagittal chin excess): This is a *positional* problem of the mandible, describing the forward position of the chin as a result of an excessively forward position of the mandible, i.e. the morphology of the chin is normal;

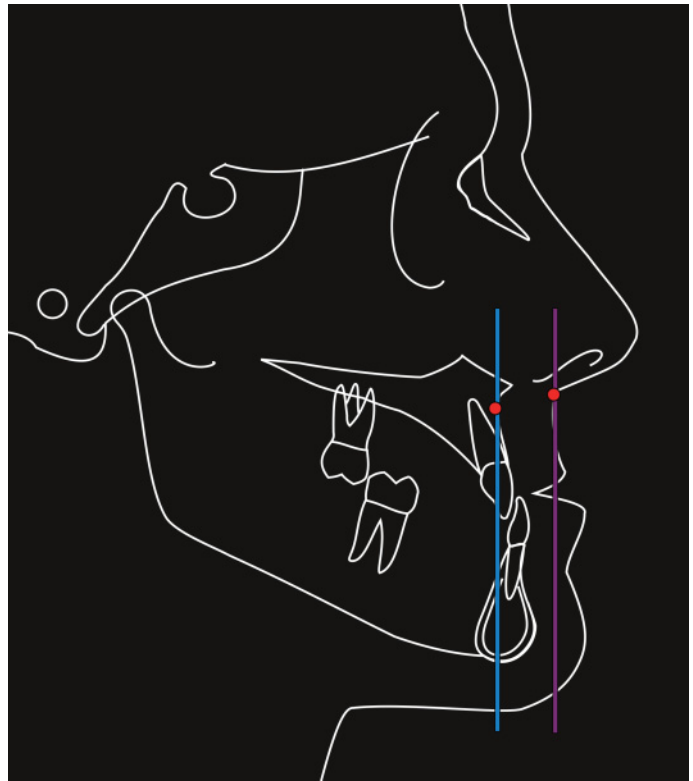


Figure 20.4 Sagittal chin excess secondary to mandibular excess (i.e. normal chin morphology on a prominent mandible).

the abnormal position of the chin is *secondary* to the abnormal position of the mandible, with the normal chin being *carried forward* on the mandible. The aetiology of secondary progenia may be due to one or a combination of the following:

- **Mandibular excess** (prognathism/macrogenathism) (Figure 20.4).
- **Hypodivergent facial growth pattern** (Figure 20.5): Alternative terms are 'horizontal facial growth pattern,' 'low angle' patient (referring to the reduced mandibular plane angle), 'short face deformity' or 'short face syndrome.' If the hypodivergent growth is the primary aetiology to a deep incisor overbite, the term 'skeletal deep bite' may be used. An element of vertical maxillary deficiency (VMD) often coincides with mild mandibular retrognathia, leading to a reduced lower anterior face height, a reduced mandibular plane angle and mandibular overclosure. This leads to an increased sagittal projection of the chin.⁹ Such hypodivergent facial growth patterns will tend to be associated with an anterior pattern of mandibular growth rotation.
- **Anterior (forward) mandibular growth rotation** (Figure 20.6A,B): Growth rotations of the mandible occur when there is a discrepancy in the amounts of growth in anterior and posterior facial heights. Anterior rotational growth of the mandible affects sagittal chin position by moving the chin upward and forward,

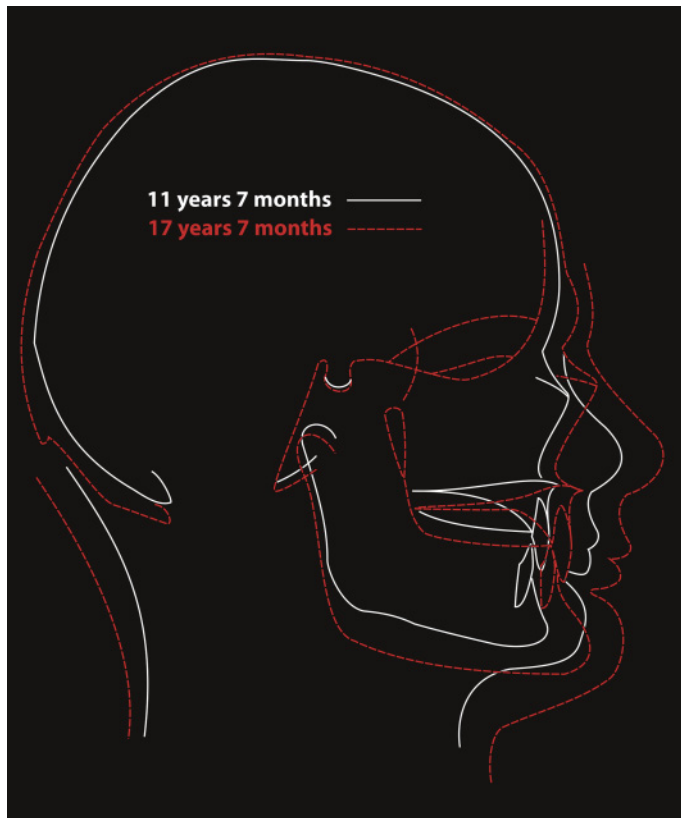


Figure 20.5 Horizontal, hypodivergent (short face type) facial growth pattern, leading to an increased sagittal projection of the chin. (Modified from Björk⁹ with permission from Informa Healthcare, Taylor and Francis Group.)

increasing the sagittal projection of the chin. Implant studies by Björk placed the centre of rotation at either the incisal edges of the mandibular incisors or at the premolars.¹⁰

- **Anterior mandibular autorotation** around the condylar hinge axis (Figure 20.7). This may be due to:
 - Loss of the dentition and associated alveolar processes leads to mandibular overclosure, with the chin rotating closer towards the nose. This has a tendency to occur with ageing.
 - Maxillary impaction surgery: The mandible will thereby autorotate forward and upward around the condylar hinge axis.
- **Anterior mandibular displacement:** In the presence of a mild Class III incisor relationship, patients with an uncomfortable edge-to-edge incisor occlusion may displace and posture the mandible anteriorly in order to achieve maximum intercuspation of the posterior teeth (see Figure 19.16).
- Any combination of the above.

‘Relative’ progenia (relative sagittal chin excess): The chin appears protrusive (too far forward) due to lower labial or

bilabial retrusion, i.e. the lower lip or both lips being positioned too far back in relation to the craniofacial complex (Figure 20.8).

Retrogenia (sagittal chin deficiency)

Retrogenia is a term used to indicate that the sagittal *position* of soft tissue pogonion (Pog') is retrusive (too far back) in relation to the rest of the craniofacial complex. This may be due to a relatively smaller size (microgenia) and/or a more posterior position of the chin.

Retrogenia is a non-specific term describing the position of the chin, not the underlying aetiology. Retrogenia may be classified as primary, secondary or 'relative'.

Primary retrogenia (primary sagittal chin deficiency): This is a *structural* problem, describing a *morphological* deformity of the chin area. An alternative and preferred term is sagittal chin deficiency. The aetiology of sagittal chin deficiency may be due to one or a combination of the following:

- Horizontal osseous microgenia (Figure 20.9B)
- Reduced thickness of soft tissue chin pad (Figure 20.9C)
- Any combination of the above.

Secondary retrogenia (secondary sagittal chin deficiency):

This is a *positional* problem of the mandible, describing the retrusive position of the chin as a result of an excessively repositioned mandible, i.e. the morphology of the chin is normal; the abnormal position of the chin is *secondary* to the abnormal position of the mandible. The aetiology of secondary retrogenia may be due to one or a combination of the following:

- **Mandibular deficiency** (retrognathia/micrognathia) (Figure 20.10).
- **Hyperdivergent facial growth pattern** (Figure 20.11): Alternative terms are 'vertical facial growth pattern', 'high angle' patient (referring to the increased mandibular plane angle), 'long/tall face deformity' or 'long face syndrome'. If the hyperdivergent growth is the primary aetiology to an anterior open bite, the terms 'skeletal open bite' or 'apertognathia' may be used. The maxilla rotates downward and backward (posterior VME), as does the mandible during growth. This leads to reduced sagittal projection of the chin.⁹ Such a vertical facial growth pattern tends to be associated with a posterior pattern of mandibular growth rotation.
- **Posterior (backward) mandibular growth rotation** (Figure 20.6C): Posterior rotational growth of the mandible affects sagittal chin position by moving the chin downward and backward, effectively reducing the sagittal projection. Implant studies by Björk place the centre of rotation at the occluding molars.¹⁰
- **Posterior mandibular autorotation** around the condylar hinge axis (Figure 20.12). This may be due to maxillary inferior repositioning – the mandible autorotates downward and backward.
- Any **combination** of the above.

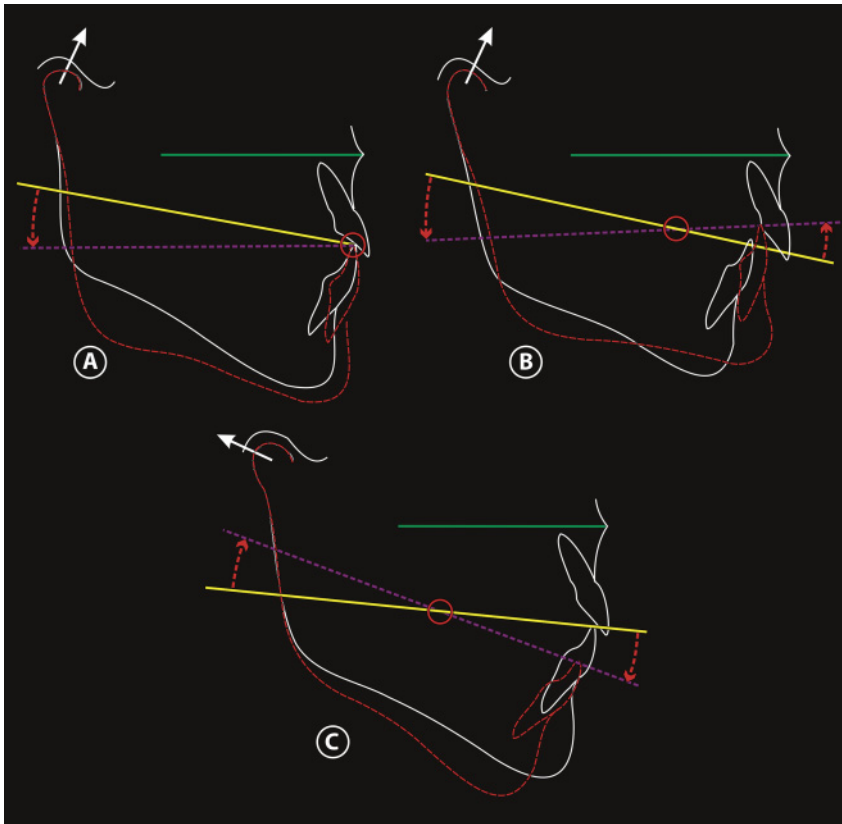


Figure 20.6 Types of mandibular growth rotation. (A) Anterior (forward) mandibular growth rotation with the centre of rotation at the incisal edges of mandibular incisors; the direction of condylar growth is upward and forward. (B) Anterior mandibular growth rotation with the centre of rotation at the premolars. In both cases, the chin moves upward and forward, increasing chin projection. (C) Posterior (backward) mandibular growth rotation moving the chin downward and backward, effectively reducing the sagittal projection. (Modified from Björk¹⁰ with permission from Elsevier.)

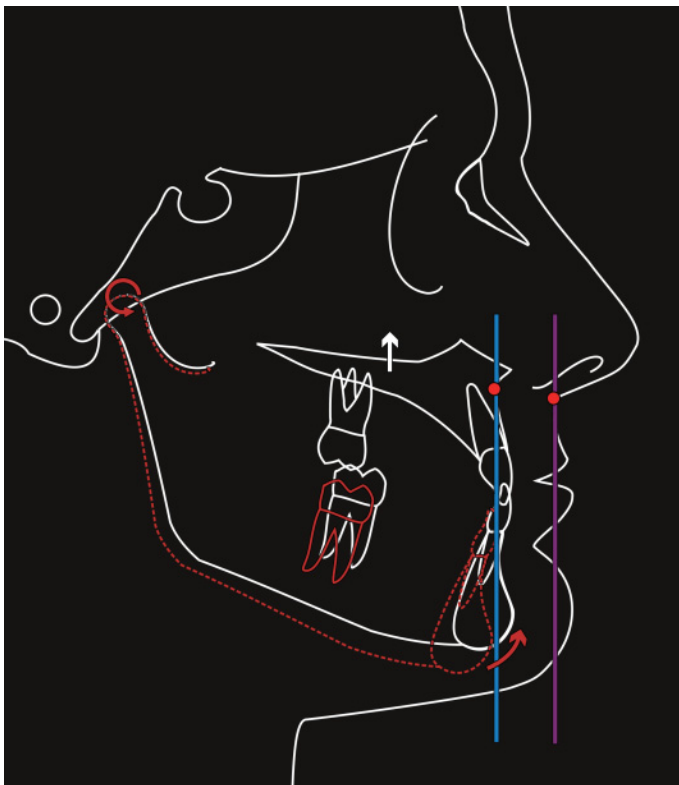


Figure 20.7 Anterior mandibular autorotation around the condylar hinge axis will increase sagittal chin projection.

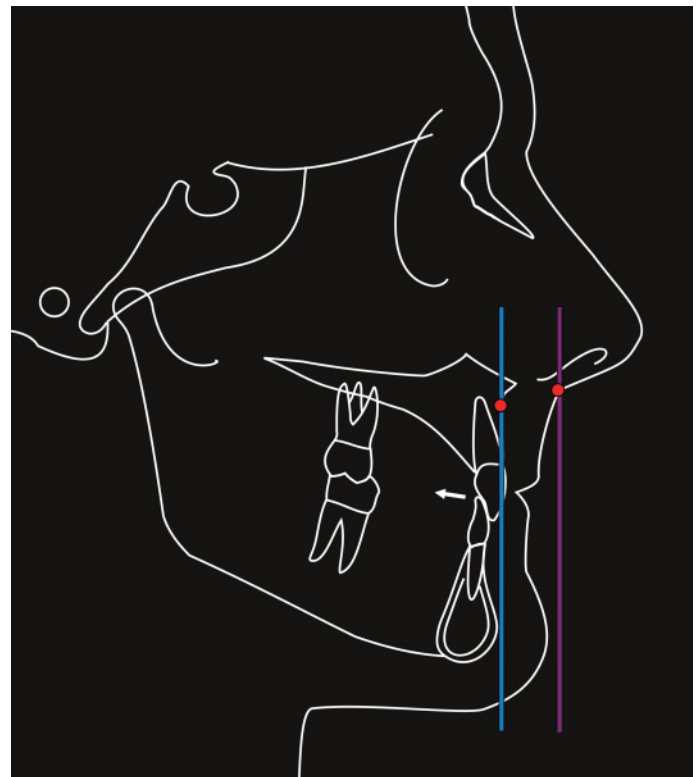


Figure 20.8 Relative sagittal chin excess, with the chin appearing protrusive (too far forward) due to lower labial or bilabial retrusion.

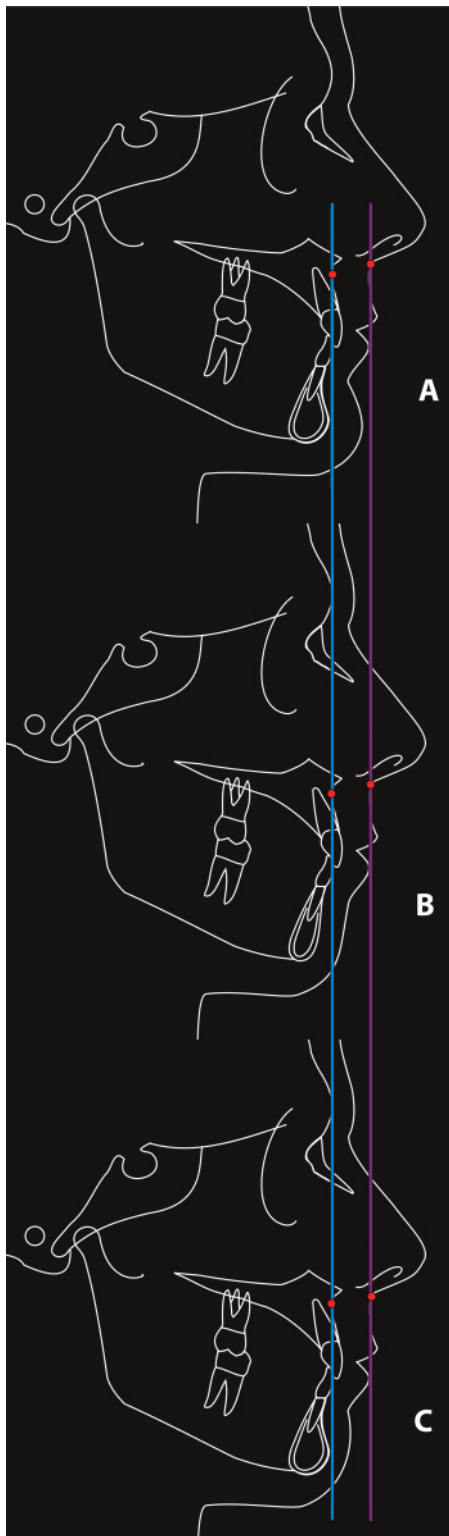


Figure 20.9 (A) Normal chin prominence; (B) horizontal osseous microgenia; and (C) reduced thickness of soft tissue chin pad.

‘Relative’ retrogenia (relative sagittal chin deficiency): The chin *appears* retrusive (too far back) due to lower labial or bilabial protrusion, i.e. the lower lip or both lips being positioned too far forward in relation to the craniofacial complex (Figure 20.13).

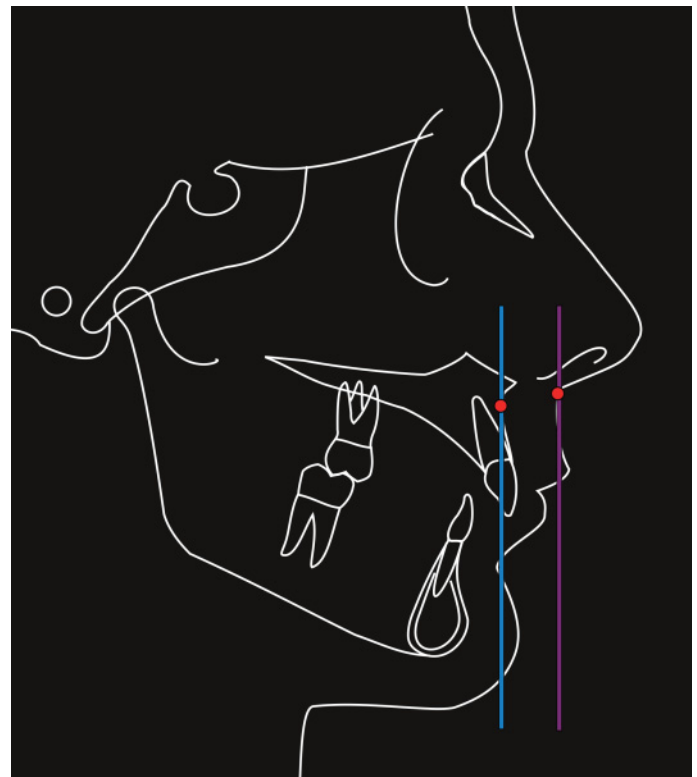


Figure 20.10 Sagittal chin deficiency secondary to mandibular deficiency (i.e. normal chin morphology on a small or retropositioned mandible).

Note

An understanding of the aetiology of chin deformity is vital for diagnosis and correct treatment planning. For example, chin excess due to mandibular prognathism requires a different approach to treatment (e.g. mandibular setback osteotomy) compared with chin excess due to horizontal osseous macrogenia (e.g. horizontal reduction genioplasty).

Note

It is particularly important to accurately diagnose chin deformities of *combined or multiple aetiology*. For example, it is possible for a patient to present with mandibular deficiency combined with horizontal macrogenia. This is a relatively common finding in patients with severe Class II, division 2 type malocclusion (Figure 20.14). The body of the mandible is retropositioned but the osseous chin is prominent. Mandibular advancement surgery to correct the dental occlusion may result in an overprojected chin requiring setback genioplasty.

Conversely, there are patients with mandibular excess and horizontal microgenia. Mandibular setback to correct the deformity and dental occlusion may therefore necessitate subsequent horizontal advancement genioplasty.

Vertical chin excess (VCE)

This term describes an increase in vertical *skeletal* chin height (Figure 20.15).



Figure 20.11 Vertical, hyperdivergent ('tall face' type) facial growth pattern, leading to a reduced sagittal projection of the chin. (Modified from Björk⁹ with permission from Informa Healthcare, Taylor and Francis Group.)

Vertical chin deficiency (VCD)

This term describes a reduction in vertical *skeletal* chin height.

Classification of chin deformities

Guyuron et al. (1995)¹¹ proposed a classification of chin deformities to be used as a guide to surgical treatment planning. They identified seven categories of chin deformities from 684 patients with *normal dental occlusions*. A modification of this classification is presented below:

Skeletal chin (mandibular symphysis):

- Macrogenia (Figure 20.16):
 - Horizontal
 - Vertical
 - Combined horizontal and vertical.
- Microgenia (Figure 20.17):
 - Horizontal
 - Vertical
 - Combined horizontal and vertical.

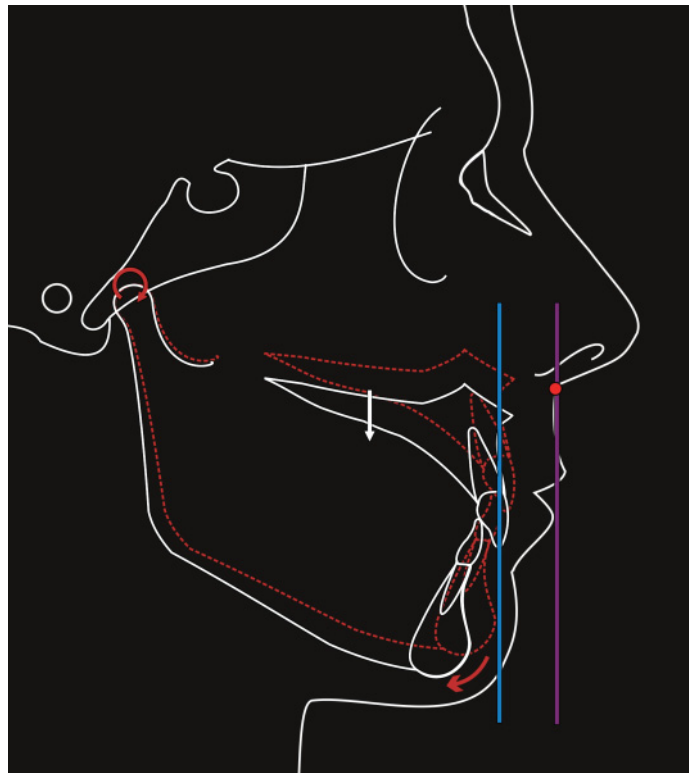


Figure 20.12 Posterior mandibular autorotation around the condylar hinge axis reduces sagittal chin projection.

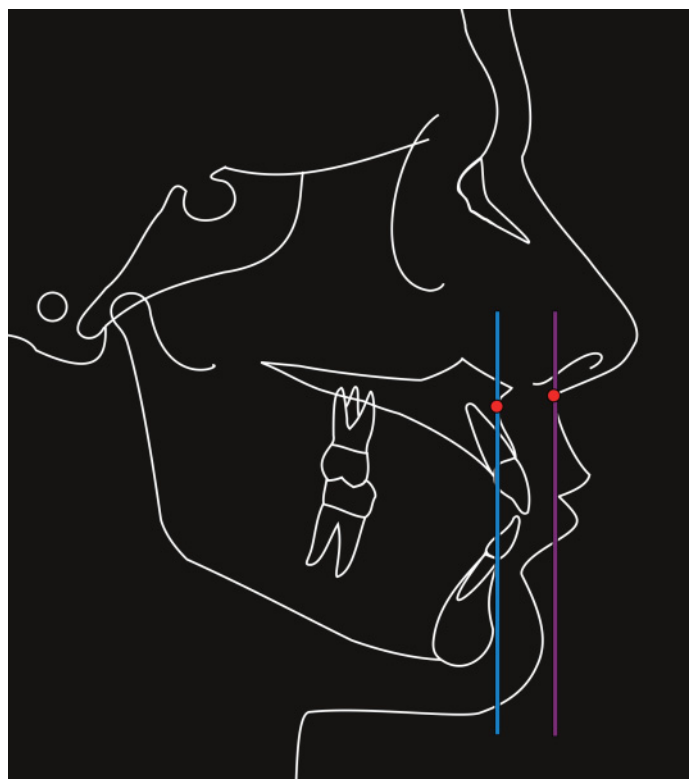


Figure 20.13 Relative sagittal chin deficiency, with the chin appearing retrusive (too far back) due to lower labial or bilabial protrusion.

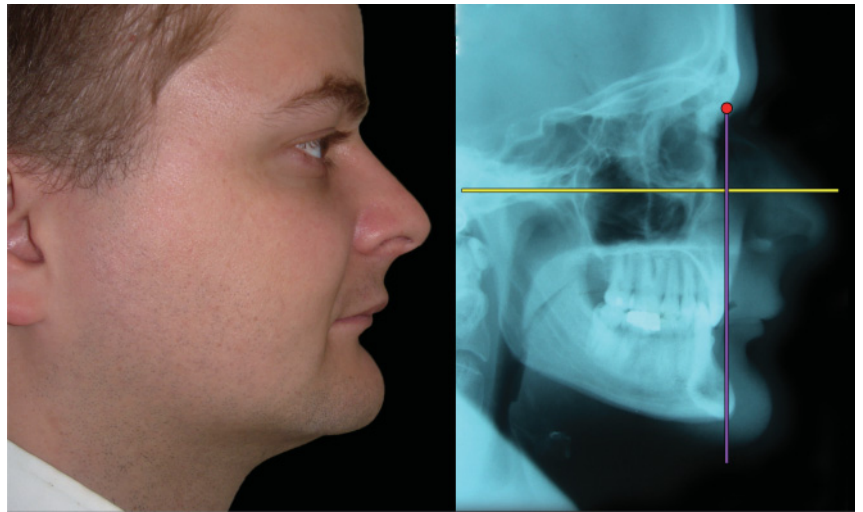


Figure 20.14 Sagittal mandibular deficiency combined with horizontal macrogenia (sagittal chin excess).

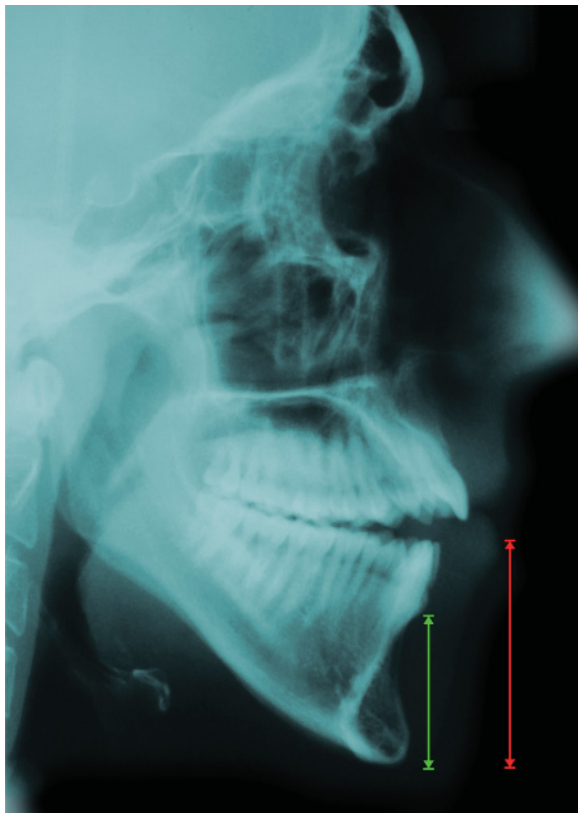


Figure 20.15 Vertical chin excess – lower anterior dentoalveolar and chin height is increased primarily as a result of an increase in skeletal chin height.

- Combined (Figure 20.18):
 - Horizontal macrogenia with vertical microgenia
 - Horizontal microgenia with vertical macrogenia.
- Asymmetric chin

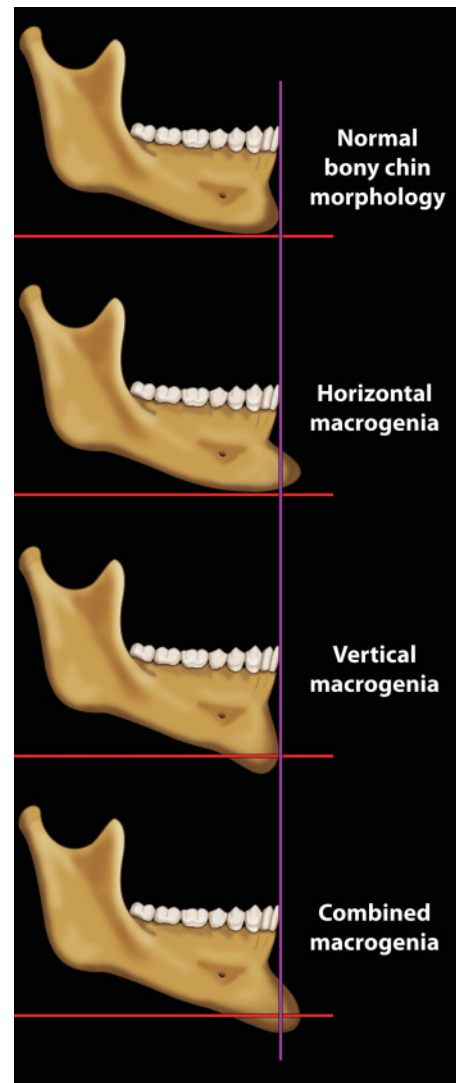


Figure 20.16 Macrogenia – types of skeletal chin excess.

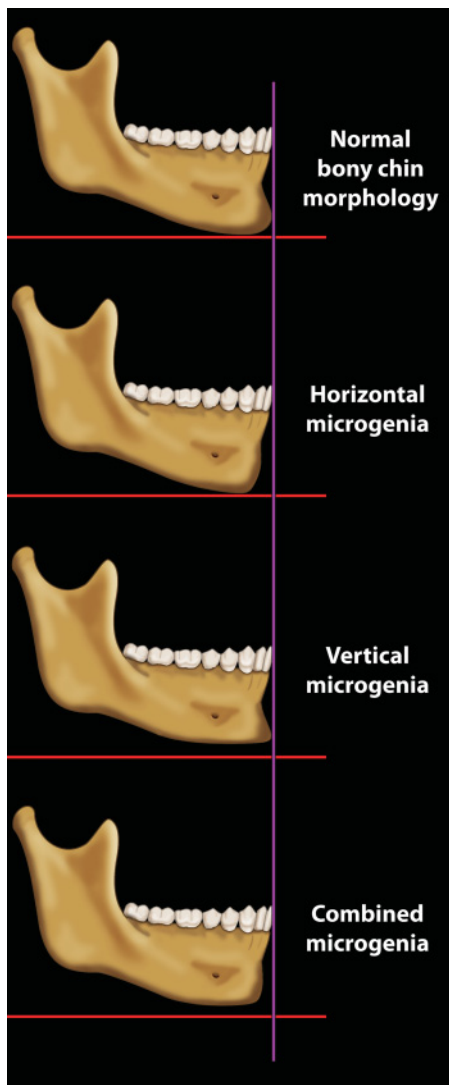


Figure 20.17 Microgenia – types of skeletal chin deficiency.

Soft tissue chin pad:

- Increased thickness of soft tissue chin pad (Figure 20.19).
- Reduced thickness of soft tissue chin pad (Figure 20.20).
- Ptosis of soft tissue chin pad (witch's chin deformity) (Figure 20.21).

Mandibular rotation:

- Chin deficiency due to posterior mandibular rotation, secondary to posterior VME in a vertical facial growth pattern and/or posterior (backward) mandibular growth rotation.
- Chin excess due to anterior mandibular rotation, secondary to VMD in a horizontal facial growth pattern and/or anterior (forward) mandibular growth rotation.

Mandibular position and/or size:

- Chin deficiency secondary to mandibular deficiency (retrognathia or micrognathia).

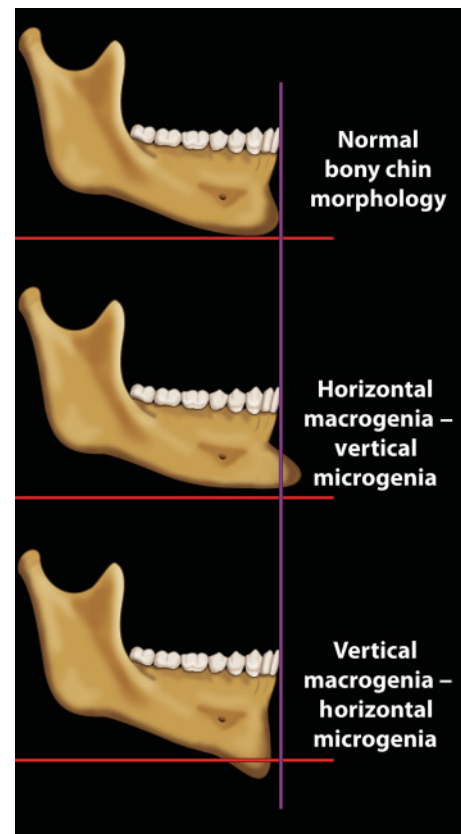


Figure 20.18 Combined skeletal chin deformity.

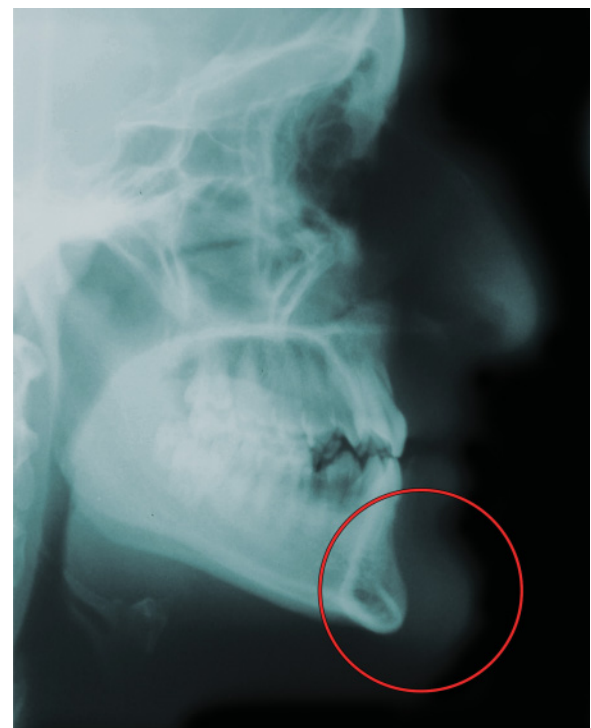


Figure 20.19 Increased thickness of soft tissue chin pad (bony chin is relatively underdeveloped).

- Chin excess secondary to mandibular excess (prognathia or macrognathia).
- Chin asymmetry secondary to mandibular asymmetry.

Clinical evaluation

The morphology of the mandible tends to be relatively consistent depending on the presenting facial deformity, e.g. a Class II, Class III, tall face or short face individual tends to have a 'typical' mandibular shape. The chin is part of the mandible; however, the morphology of the osseous chin, or mandibular symphysis, and the overlying soft tissue chin pad is *highly variable* in all three planes of space, even with the same basic types of facial deformities. Therefore, the chin must be evaluated as an **independent facial aesthetic unit**.

When evaluating the chin, the following patient positioning guidelines should be observed:

- **Natural head position (NHP):** The patient must be examined in NHP. It is not uncommon for patients to develop a

compensatory head posture in order to minimize the aesthetic impact of their facial appearance, e.g. Class II patients may tilt their heads up to increase their chin prominence, Class III patients may tilt their heads down to reduce chin prominence.

- **Mandibular rest position:** It is important that the mandible is not postured or overclosed:
 - **Mandible postured:** Patients with Class II skeletal relationships may have a tendency to posture the mandible anteriorly. Some patients become so used to these postured positions, which may be up to 10 mm, that it is possible for the clinician to miss the postured position.
 - **Mandible overclosed:** This is particularly common in patients with maxillary hypoplasia.
- **Soft tissues in repose:** The facial soft tissues must be at rest, in particular avoiding any lip strain to achieve a lip seal.

Note

A useful technique for getting the mentolabial soft tissues in repose is as follows. Ask the patient to relax their lips and to keep their teeth lightly together. Then place very gentle finger pressure on the mentolabial fold, pressing inwards and downwards to relax the mentalis muscle, while asking the patient to relax their lips. This may need to be repeated a few times until the patient can maintain their lips in repose.

Systematic evaluation of the chin is critical for correct diagnosis and the establishment of an accurate and effective treatment plan. The chin must be analysed in the sagittal, vertical and transverse spatial planes.

Sagittal evaluation and chin projection

Sagittal chin projection is an important parameter in the aesthetics of the lower facial third. Excessive chin prominence is unattractive; conversely, a deficient chin leads to an indistinct

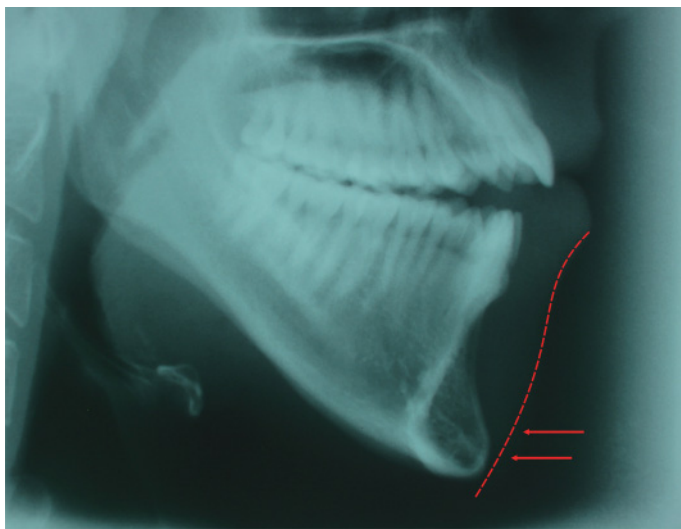


Figure 20.20 Reduced thickness of soft tissue chin pad (mentalis hypertrophy is evident at a higher level to the chin).



Figure 20.21 Ptosis of the soft tissue chin pad in repose and in animation.

lower face merging with the neck, which may be even more unattractive.

The degree of sagittal projection of the chin (and the possible aetiology) may be evaluated in profile view with a number of analyses. It is imperative to determine the sagittal position of soft tissue and skeletal pogonion and the thickness and morphology of the soft tissue chin pad. *No single analysis will be ideal for all patients.* A number of analyses based on different reference lines may be used depending on the facial type and presenting deformity. The first step is to define the aetiology of the deformity. Increased or reduced sagittal projection of the chin may be due to one or a combination of the following factors:

- **Skeletal factors:**
 - The sagittal position of the mandible (retrognathic or prognathic)
 - The size of the mandible (micrognathic or macrognathic)
 - The size and sagittal projection of the bony chin (horizontal microgenia or horizontal macrogenia)
 - Anterior or posterior growth rotation of the mandible.
- **Soft tissue factors:**
 - The thickness of the soft tissue chin pad (reduced or increased).
- **Relative position:**
 - Mandibular autorotation: Anterior or posterior rotation of the mandible about the condylar hinge axis, e.g. Class III incisor relationship with loss of posterior teeth and hence no posterior dental occlusion will lead to overclosure of the mandible and increased projection of the chin (see Figure 19.15).
 - Anterior mandibular displacement in Class III patients (see Figure 19.16).

Sagittal position of soft tissue chin

The sagittal prominence of the soft tissue chin (pogonion, Pog') may be evaluated in relation to:

- **Facial vertical planes:** The horizontal distance of soft tissue pogonion (Pog') may be measured in relation to a number of facial vertical planes, including:

- Zero meridian (0°-meridian) plane (Gonzalez-Ulloa)^{12,13}
- Vertical plane perpendicular to the Frankfort Horizontal plane, through subnasale (Wolford et al.)^{14,15}
- True vertical plane (perpendicular to a true horizontal plane) through soft tissue nasion or glabella
- True vertical plane (perpendicular to a true horizontal plane) through subnasale (Bell et al.,¹⁶ Bass^{17,18})
- Vertical corneal plane.
- **Facial angular relationships:**
 - Angle of facial profile convexity (Legan and Burstone)¹⁹
 - Facial angle (Holdaway).^{20,21}
- **The upper and lower lips:**
 - Riedel plane (Riedel).²²
- **The aesthetic planes** (E-line, S-line, H-line, etc; see Chapter 17).
- **The inclination and position of the upper lip.**
- **The sagittal prominence of the lower lip.**

Zero-degree meridian

The Mexican plastic surgeon Mario Gonzalez-Ulloa^{12,13} proposed that soft tissue pogonion (Pog') should be on a vertical line dropped from soft tissue nasion, perpendicular to the Frankfort Horizontal plane, described as the zero-degree meridian (or meridian 0° of the face) (Figure 20.22).

If the sagittal position of nasion is not acceptable, it may be adjusted to a more ideal position. The alternative is to use soft tissue glabella¹⁹ or a point midway between nasion and glabella.

Note

As a result of the modern perceived attractiveness for a slightly more prominent lower face, a **modified 0°-meridian** may be employed, with soft tissue glabella substituted for soft tissue nasion, and the true horizontal plane substituted for the Frankfort Horizontal plane.

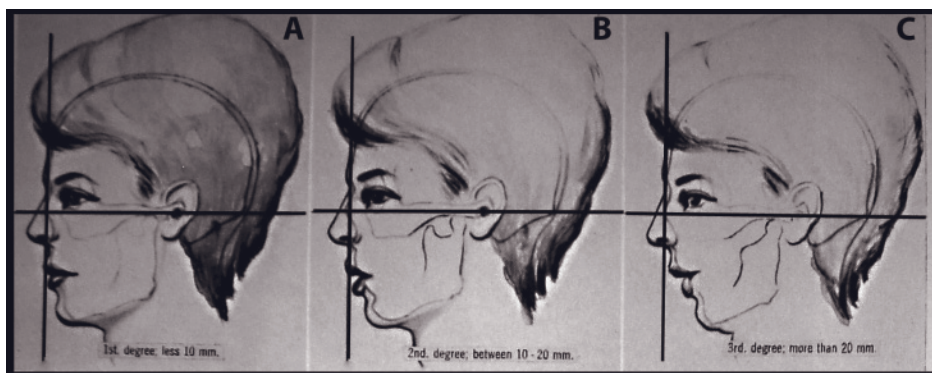


Figure 20.22 Zero-degree meridian: according to Gonzalez-Ulloa^{12,13} soft tissue pogonion should be on this line; chin retrusion up to 10mm was termed first degree, between 10–20mm was second degree and greater than 30 mm was third degree. (Modified from Gonzalez-Ulloa and Stevens¹³ with kind permission of Wolters Kluwer Health.)

Note

Due to the biological variability inherent in the orientation of the Frankfort Horizontal plane, ideally it may be replaced by the true horizontal plane.

Such vertical and horizontal aesthetic planes are evident in the original work of Leonardo da Vinci (see Figure 6.12).

Vertical plane perpendicular to Frankfort Horizontal (FH) plane, through subnasale

Proposed by Wolford et al.,^{14,15} the horizontal distance from soft tissue pogonion (Pog') to a line perpendicular to the Frankfort Horizontal (FH) plane may be measured.

- The mean value is -3 ± 3 mm (i.e. 3 mm posterior to the vertical line ± 3 mm).

True vertical plane through soft tissue nasion (or glabella)

With the patient in NHP, the true vertical plane may be drawn (perpendicular to the true horizontal plane) through nasion. This is effectively the 0°-meridian of Gonzalez-Ulloa, but using a true vertical plane, rather than a vertical plane perpendicular to the Frankfort Horizontal plane. As with the 0°-meridian, glabella may be used instead of nasion, or a point between the two, depending on the anatomy of this area (Figure 20.23).

- Soft tissue pogonion (Pog'): 0 ± 2 mm from this line.

True vertical plane through subnasale

With the patient in NHP, the true vertical plane may be drawn (perpendicular to the true horizontal plane) through subnasale. A number of analyses have suggested using subnasale rather than soft tissue glabella or nasion as the landmark through which to draw the vertical line perpendicular to the true horizontal line or Frankfort Horizontal plane. The suggested reason is that subnasale is closer to the lower face and thereby a more reasonable landmark to use in evaluating lower facial relationships. This depends to a great extent on the sagittal position of subnasale, which is dependent on the sagittal position of the maxilla.

- Bell et al.¹⁶ suggested the sagittal position of soft tissue pogonion should be 1–4 mm posterior to the subnasale vertical (SnV) line.
- **Bass aesthetic analysis:**^{17,18} suggests drawing a vertical perpendicular from the 'Aesthetic Horizontal' (essentially the true horizontal plane), halfway between subnasale and maxillary A-point. This line provides the *posterior limit* of the chin, behind which the chin will appear retrusive. A second vertical line is drawn through subnasale, providing the *anterior limit* of the chin. Anterior to this line (essentially the



Figure 20.23 With the patient in natural head position, the true vertical plane (TrV) may be drawn through nasion. Soft tissue pogonion should be 0 ± 2 mm from this line. TrH, true horizontal.

subnasale vertical line), the chin will appear protrusive (Figure 20.24).^{23,24}

Vertical corneal plane

A vertical plane may be drawn perpendicular to the Frankfort Horizontal plane (or a true vertical plane may be drawn) at the position of the cornea. In North American white Caucasians, pogonion (Pog') has been found to be 2–9 mm (4–7 mm in women) anterior to this vertical corneal plane (Figure 20.25).²⁵

Angle of facial profile convexity (clinical/soft tissue)

Legan and Burstone¹⁹ described the angle of facial profile convexity, which provides an indication of the sagittal position of soft tissue pogonion (Pog') in relation to an extension of the upper facial plane (G-Sn). A line drawn from glabella (G') to subnasale (Sn) is extended. Another line drawn from subnasale to soft tissue pogonion forms an angle at subnasale – the angle of soft tissue profile convexity. If soft tissue pogonion is behind the original extended line, then the angle formed at subnasale will be positive and vice versa (see Figure 8.11).

- The mean value is estimated to be $12^\circ \pm 4^\circ$.

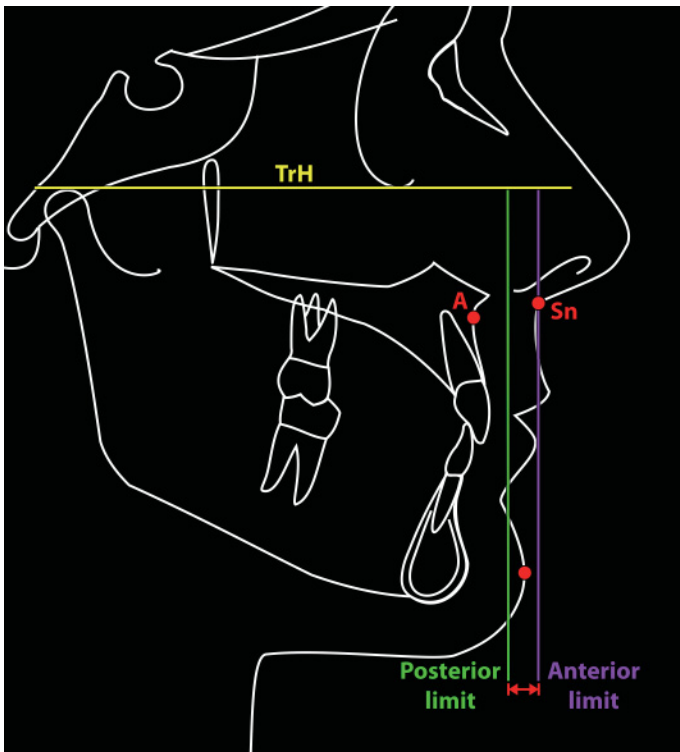


Figure 20.24 Bass aesthetic analysis^{17,18} suggests drawing a true vertical line halfway between subnasale (Sn) and maxillary A-point. This line provides the posterior limit of the chin, behind which the chin will appear retrusive. A second vertical line is drawn through subnasale, providing the anterior limit of the chin. Anterior to this line (essentially the subnasale vertical line), the chin will appear protrusive. TrH, true horizontal.

Facial angle (clinical/soft tissue)

The facial angle (Holdaway^{20,21}) indicates the relative sagittal prominence of soft tissue pogonion (Pog'). It is formed by the intersection of true horizontal line (or Frankfort horizontal plane) with a facial vertical plane (N'-Pog') (see Figure 8.12).

- The angle should be 90–92°.

A greater angle indicates prominence of soft tissue pogonion; an angle less than 90° indicates retrusion of soft tissue pogonion.

The soft tissue facial angle does not of itself determine the aetiology of the sagittal position of soft tissue pogonion. Consequently, the facial angle must be used in conjunction with other measurements and analyses. In addition, when constructing the facial vertical plane, if the sagittal position of nasion is not acceptable, it may be adjusted to a more ideal position. The alternative is to use soft tissue glabella rather than nasion.

Riedel plane

This method, described by the orthodontist Richard Riedel,²² indicates that the point of maximum chin projection is on a line tangent to the upper and lower lips (Figure 20.26). This is a simple and useful method of analysis, but depends on the sagittal

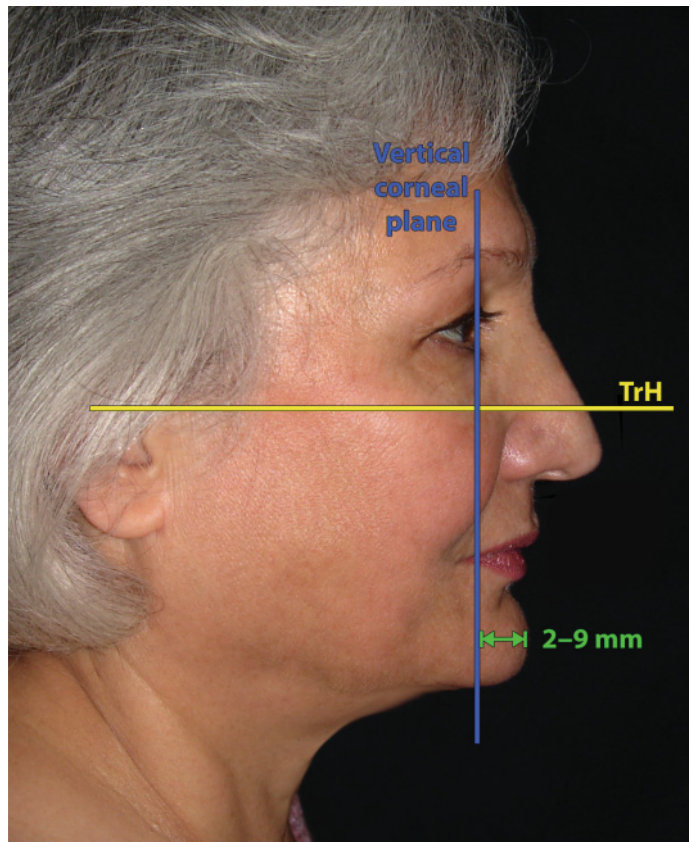


Figure 20.25 Soft tissue pogonion (Pog') should be 2–9mm anterior to the vertical corneal plane. TrH, true horizontal.

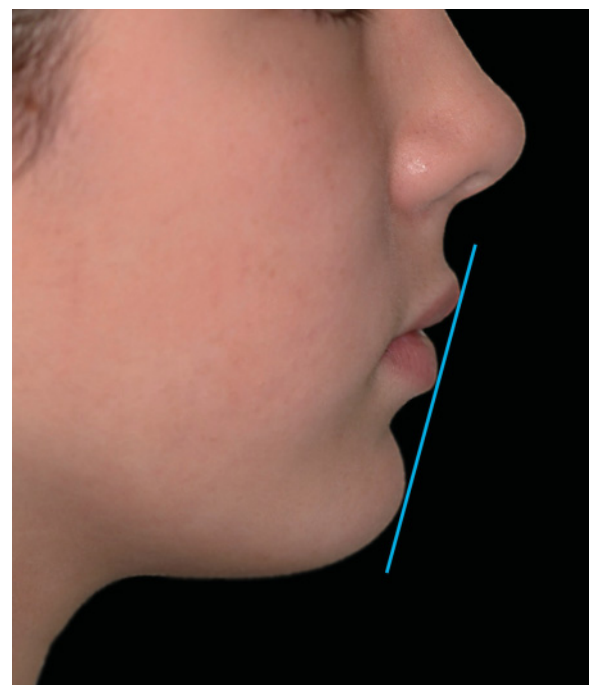


Figure 20.26 The Riedel analysis indicates that the point of maximum chin projection is on a line tangent to the upper and lower lips; this analysis depends on the sagittal lip position being correct.

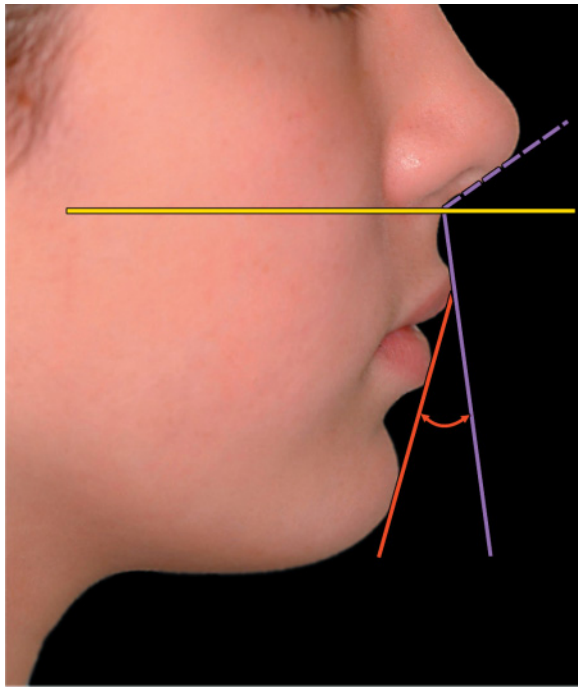


Figure 20.27 Evaluation of the sagittal position of the chin in relation to the inclination and prominence of the upper lip (lower component of the nasolabial angle).

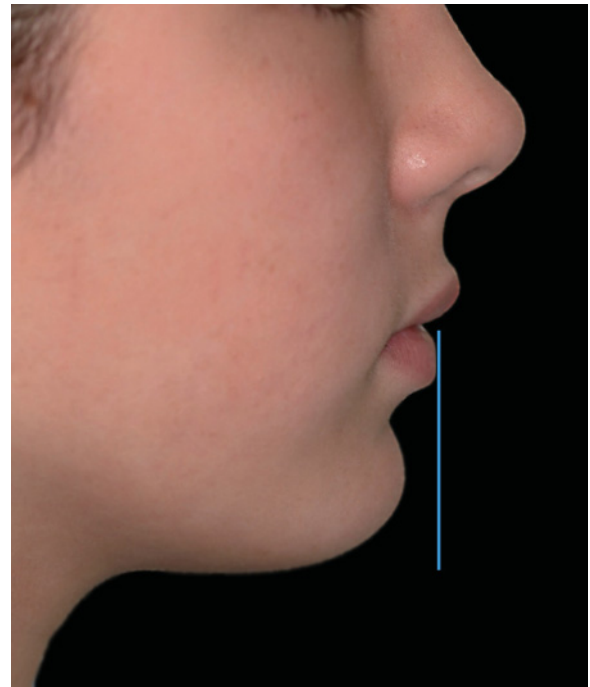


Figure 20.28 As a general guideline, soft tissue pogonion (Pog') should *not* be further ahead than the lower lip in the sagittal plane (patient in NHP).

lip position being correct. It is therefore useful in planning genioplasty in patients with isolated sagittal chin deformity, where the sagittal mandibular (excluding chin) and lip position is correct.

Aesthetic planes

The aesthetic planes are described in Chapter 17 (see Figure 17.33).

Inclination and position of the upper lip

A potentially useful method of evaluating the sagittal position of the chin is in relation to the inclination and prominence of the upper lip (lower component of the nasolabial angle). Drawing a true horizontal line through subnasale takes the nasal columella out of the equation. As the upper lip becomes more prominent, the chin does likewise, maintaining their relative relationship. This technique may be useful for planning advancement or setback genioplasty or mandibular surgery, particularly in Class II patients with good upper lip position and morphology. An 'ideal' angle of 25° (range 15–30°) is evident from analysis of classical and Renaissance sculpture and art and attractive female faces, but normative values are not yet available (Figure 20.27).

Sagittal prominence of lower lip

With the patient in NHP, as a general guideline soft tissue pogonion (Pog') should *not* be further ahead than the lower lip in the sagittal plane (Figure 20.28).²⁶

Note

This guideline has important clinical implications in the planning of genioplasty to camouflage chin deficiency secondary to mandibular deficiency, where the small or retrusive mandible is responsible for the patient's perception of a small chin. Patients with mandibular deficiency and associated lack of chin projection will often complain of a 'small chin' or 'weak chin'. However, an additional aesthetic feature of mandibular deficiency is a **retrusive lower lip**. The ideal management of such cases is combined orthodontic-orthognathic surgical correction, advancing the mandible and thereby *correcting the sagittal position of the lower lip and chin*. Patients who do not want to go through such extended treatment may opt for camouflage advancement genioplasty. Genioplasty can effectively camouflage the visual perception of a 'weak' chin, but *cannot correct the retrusive lower lip*. This limitation restricts the forward movement of the chin so as not to advance it beyond the retrusive lower lip.

In such patients the *most important determinant of the extent of anterior movement of the chin is the abnormal, retrusive position of the lower lip*; a structure that cannot be altered with isolated genioplasty. This restrictive forward movement of the chin, frequently only 3–4 mm, may leave the chin underprojected. Rosen²⁶ has demonstrated that simultaneous inferior repositioning of the chin with such modest advancement will lead to an increase in the volume of the lower face, open the often exaggerated mentolabial fold and lead to overall improved lower facial aesthetics (Figure 20.29).



Figure 20.29 (A) Patient with mandibular deficiency and associated retrusive lower lip. (B) Sagittal advancement of the chin beyond the lower lip will result in an overprojected chin. (C) Simultaneous inferior repositioning of the chin with modest advancement will provide a better compromise than sagittal advancement. (Images B and C were created using computer manipulation.) (D) Actual result with mandibular advancement, correcting the sagittal position of the chin and lower lip, while also correcting the Class II dental occlusal relationship. Note also the significant improvement in submental-cervical aesthetics.

Note

Sex differences: A general guideline is that women tend to accept a slightly reduced chin projection, whereas men tend to accept slightly increased chin projection; this does depend to a great extent on the relative prominence of the nose and lips in both sexes.

Zide et al.²⁷ stated that sagittal augmentation of the chin tends to make the chin appear vertically longer. Due to this and the sex differences already described, they advise undercorrection of a sagittally deficient chin in women.

Sagittal position of hard tissue (skeletal) pogonion

Nasion perpendicular (McNamara)

With the patient's head oriented in NHP, the most direct method to determine the sagittal position of the mandible is to measure the horizontal linear distance to the nasion perpendicular (N-perpendicular), a vertical line perpendicular to the true horizontal, dropped from nasion. Points anterior to N-perpendicular are assigned a positive value, and posterior a negative value (see Figure 7.14). In white Caucasian patients:²⁸

- Mandibular point B is 2–3 mm behind nasion perpendicular
- Hard tissue pogonion (the most anterior point on the bony chin) is:
 - –4 to 0 mm behind N-perpendicular (in adult women)
 - –2 to +5 mm to N-perpendicular (in adult men).

Facial angle (cephalometric/skeletal)

Downs²⁹ described the facial angle as the inferior inside angle in which the facial line (N-Pog) intersects the Frankfort plane. Downs found a mean value of 88° with a range of 82–95°. It indicates the relative sagittal position of the mandible/chin to the upper face (see Figure 8.12).

Relationship to the anterior cranial base (SNB, SND and SN-Pog)

See Figure 7.22.

Linear relationship of anterior mandible to gonion at three levels

Linear measurements from gonion may be used to compare the relative position of the mandibular incisor edges, mandibular alveolar B-point and pogonion. The following normative values are based on young Caucasian adults (Figure 20.30).^{30,31}

- Gonion-lower incisor incisal edge (Go-LiE):
 - Male: UK 77 ± 5 mm;³⁰ US 88 ± 5 mm³¹
 - Female: UK 71 ± 3 mm;³⁰ US 80 ± 6 mm.³¹
- Gonion-Point B (Go-B point):
 - Male: UK 73 ± 4 mm;³⁰ US 81 ± 4 mm³¹
 - Female: UK 67 ± 3 mm;³⁰ US 77 ± 4 mm.³¹
- Gonion-Pogonion (Go-Pog):
 - Male: UK 79 ± 4 mm;³⁰ US 87 ± 4 mm³¹
 - Female: UK 72 ± 4 mm;³⁰ US 82 ± 4 mm.³¹

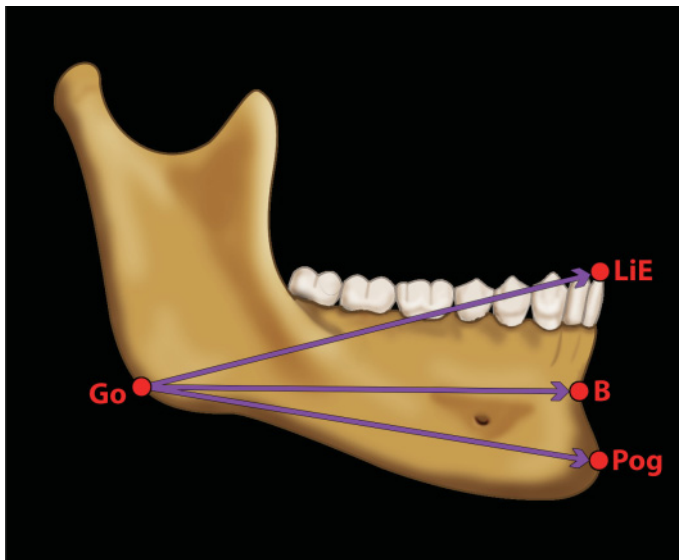


Figure 20.30 Linear relationship of anterior mandible to gonion at three levels. Comparison of the relative distances is more important than the absolute values. Go, gonion; LiE, lower incisor edge, alternatively termed incision inferius incisalis; B, alveolar B-point; Pog, pogonion.

Note

The relative values are more important than the absolute values. The Go-Pog distance is almost the same as Go-LiE, with Go-B point a few millimetres behind in position. Increased differences may suggest altered mandibular incisor inclination and/or macrogenia/microgenia.

Projection of chin in relation to mandibular body

The sagittal projection of the skeletal chin in relation to the mandibular body may be evaluated from the sagittal position of pogonion (Pog) in relation to the nasion-B-point line (NB line).^{32,33} The amount of bony chin anterior to this line may be referred to as the *effective chin*. Ideally, pogonion should project 4–6 mm anterior to the NB line.

Projection of chin in relation to mandibular incisors

Holdaway^{20,21} originated the concept, also incorporated into the Steiner cephalometric analysis, that the distance the labial surface of the mandibular incisors are in front of the NB line should equal the amount of *effective chin* ahead of the NB line. This **Holdaway ratio** (Li-NB: Pog-NB) may be useful when planning surgical repositioning of the chin. A 2 mm discrepancy between these measurements is acceptable; over 4 mm discrepancy often requires treatment (Figure 20.31).

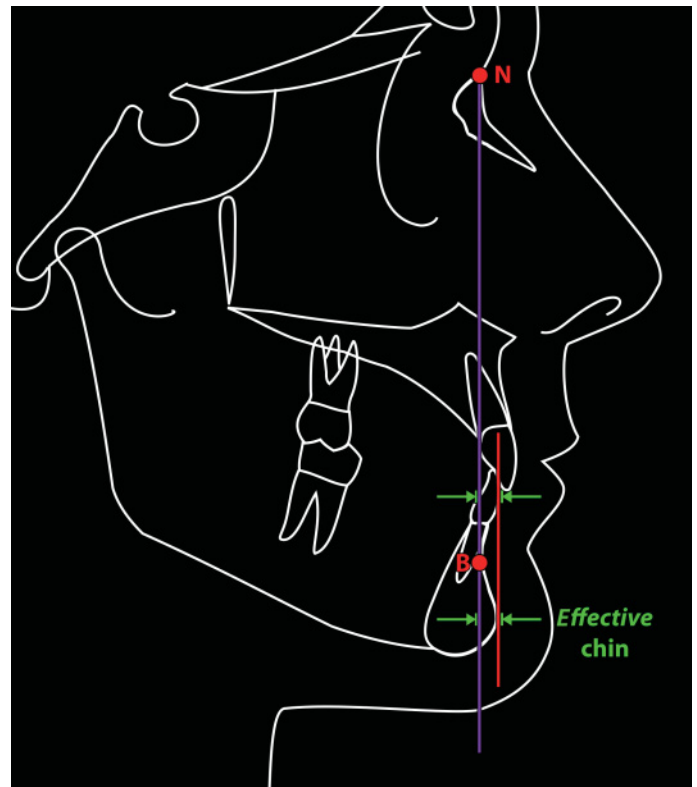


Figure 20.31 Projection of chin in relation to mandibular incisors. The labial surface of the mandibular incisor should lie equally as far ahead of the NB line as does the bony pogonion.

Projection of chin in relation to the A-Pog line

An aesthetic guideline describes the mandibular incisor edges as lying 1 ± 2 mm ahead of a line constructed between maxillary A-point and bony pogonion, also known as the A-Pog line (see Figure 7.41).³⁴ Consequently, a line drawn from A-point through a point 1 mm behind the mandibular incisor tip and extending inferiorly would define the anterior location of pogonion.

Note

As a general guideline, the bony chin (pogonion) must not be advanced more than a few millimetres anterior to the mandibular incisor teeth.

Rees aesthetic plane

This line/plane, described by the American plastic surgeon Thomas D Rees, is formed between the nasal tip (pronasale) and the upper lip (labrale superioris) in profile view.³⁵ In an attractive facial profile with normal relationship between the lower and midfacial hard and soft tissue structures, the line should pass on or near *skeletal* pogonion (Figure 20.32). This analysis is dependent on the nasal tip projection and sagittal position of the upper lip. It does not take into account the thickness of the soft tissue chin pad.

Note

Every hard tissue analysis and guideline must take into account the thickness of the soft tissue chin pad, changes to the chin pad in smiling and the anatomy and activity of the mentalis muscle.

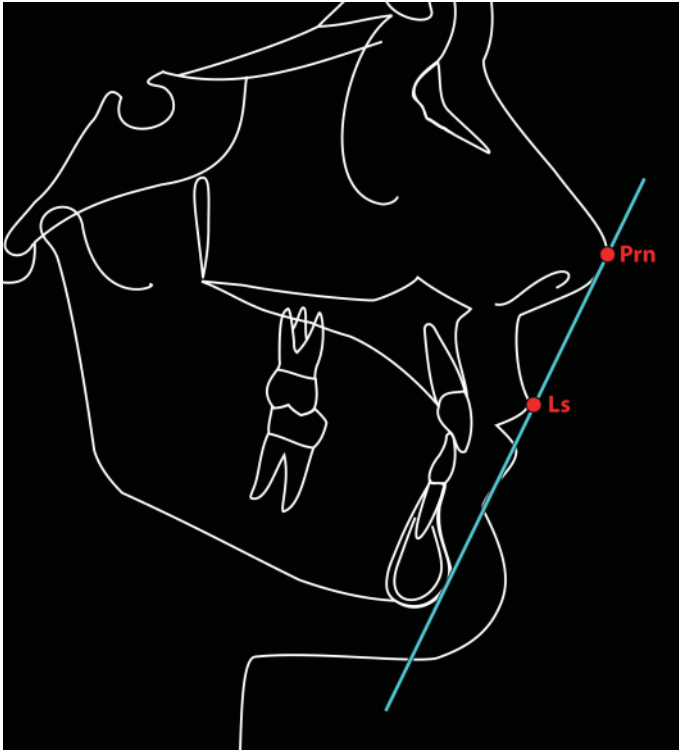


Figure 20.32 Rees aesthetic plane – this line/plane, drawn between the nasal tip (Prn) and the upper lip (Ls) in profile view, should pass on or near *skeletal* pogonion.

Indirect morphological influences on sagittal chin projection

The sagittal prominence of the chin is *indirectly* related to four linear and three angular craniofacial parameters. Changes in any of these parameters, particularly with growth, will indirectly influence the prominence of the chin. These parameters were described by the orthodontist Milo Hellman,³⁶ the modification of which is evident in the Björk polygon (Figure 20.33).³⁷

- Linear parameters:
 - Anterior cranial base (SN) length
 - Posterior cranial base height (S-Ar)
 - Lower posterior face height (Ar-Go)
 - Mandibular body length (Go-Me).
- Angular parameters:
 - Saddle angle
 - Articular angle
 - Gonial angle.

Soft tissue chin pad

The soft tissue chin pad is a highly variable area. The thickness of this area is variable, with an average value of 10 ± 2 mm. The Holdaway analysis provides a figure of 10–12 mm as ideal.^{20,21}

An important part of the clinical evaluation is *palpation* of the chin area, in order to assess the thickness of the soft tissue chin. The soft tissue chin pad thickness should be palpated just lateral to the midline as the chin pad tends to be thinnest in the centre. Further measurement is possible on the lateral cephalometric radiograph.

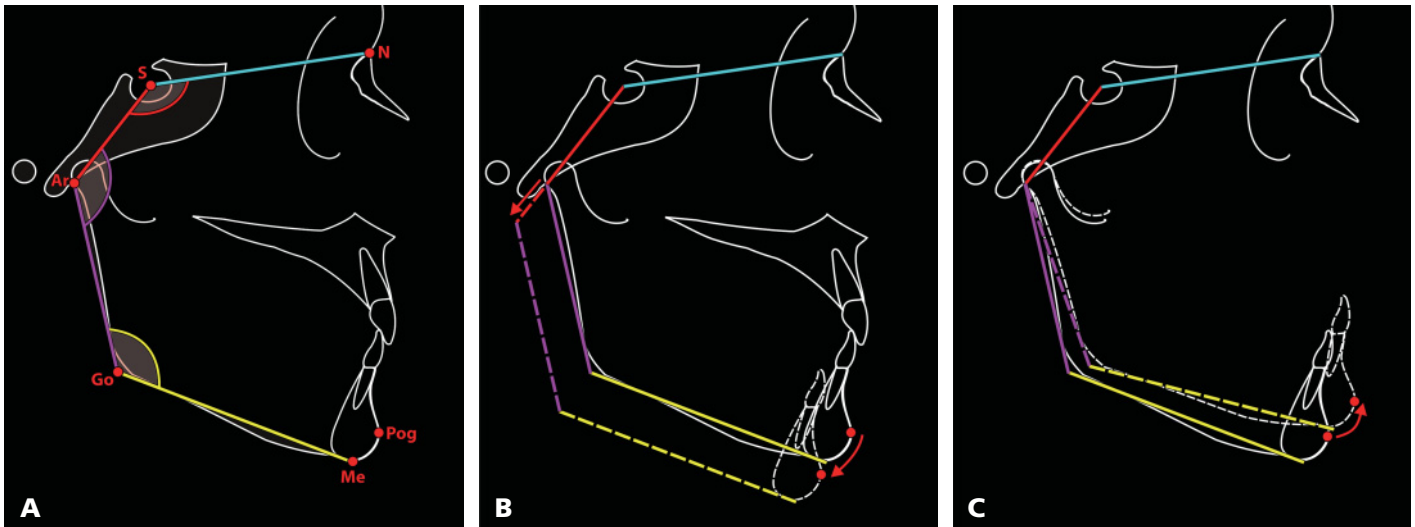


Figure 20.33 (A) Björk's polygon demonstrates four linear and three angular craniofacial parameters, which may *indirectly* influence the prominence of the chin. (B) An increase in posterior cranial base height (S-Ar) will indirectly reduce the sagittal prominence of the chin. (C) A reduction in the articular angle will indirectly increase chin prominence.

Figure 20.34 The morphology of the mentolabial fold and the transition between the lower lip and chin is arguably more important than the sagittal projection of the chin. **(A)** Reduced fold depth and obtuse mentolabial angle. **(B)** 'Ideal' mentolabial relationship. **(C)** Deep mentolabial fold and acute mentolabial angle. The three figures each have the same sagittal chin position.

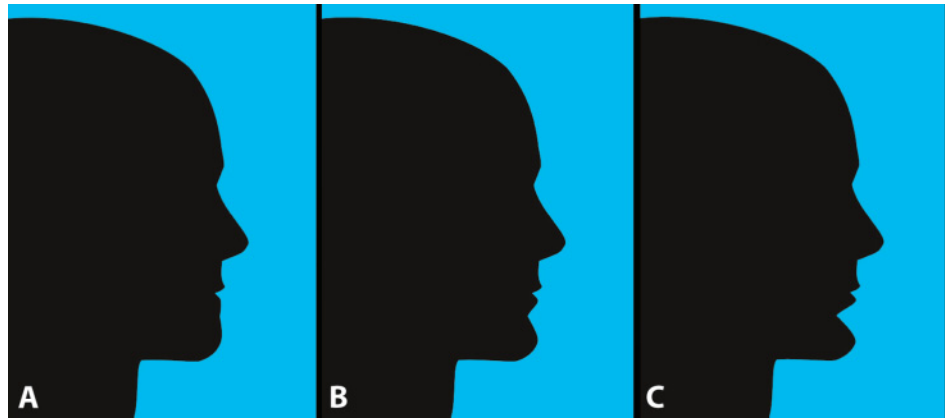


Figure 20.35 In patients with horizontal osseous macrogenia and a thin soft tissue chin pad (<4mm), the smile will efface the chin pad, resulting in greater apparent prominence of the underlying osseous chin. Such patients will require greater bony chin reduction than if the chin prominence is due to excessive thickness of the soft tissue chin pad.



Note

Horizontal macrogenia due to increased thickness of the soft tissue chin pad must be diagnosed, as osseous horizontal reduction genioplasty of normally positioned bone will lead to a very poor aesthetic outcome, flattening the chin pad and increasing submental fullness.²⁶ In patients requiring orthognathic surgery, reducing the prominence of the chin by clockwise rotation of the bimaxillary complex will reduce the sagittal projection of the chin without resorting to surgery of the chin area.

Mentolabial fold and chin pad morphology

Evaluation of the sagittal projection of the chin is an important part of lower facial analysis. However, the overall aesthetics of the lower face is strongly related to the morphology of the **mentolabial fold-chin pad transition**. The same projection of the soft tissue chin pad may occur with significantly different mentolabial morphology, with varying aesthetic appearance (Figure 20.34).³⁸ The depth of the mentolabial fold and the mentolabial angle are important considerations (see Chapter 18). The morphology, thickness and projection of the lower lip may also vary considerably with the same sagittal chin projection.^{39,40}

Dynamic chin pad evaluation

Relationship between chin pad thickness and smiling

In patients with horizontal macrogenia, the excessive projection of the chin may be due to excessive thickness of the soft tissue chin pad, osseous macrogenia or both. When the chin pad is excessively thick, the smile will efface the chin pad, reducing the apparent prominence and improving the appearance of the chin profile. Conversely, patients with horizontal osseous macrogenia and a thin soft tissue chin pad (<4mm), the smile will again efface the chin pad, resulting in a more obvious prominence of the underlying osseous chin projection (Figure 20.35). Therefore, the latter case will require greater bony reduction.⁴¹

Horizontal smile/chin ptosis phenomenon

In normal smiling, the oral commissures (corners of the mouth) are elevated, which in turn elevates the soft tissue chin pad. Zide and Boutros⁴² described the **horizontal smile/chin ptosis phenomenon**: certain individuals smile without elevating the corners of the mouth; with this horizontal, non-lifting smile, the depressors of the lower lip are essentially unopposed and thus the central part of the lower lip is pulled down in tandem, leading to dynamic chin ptosis (Figure 20.36).



Figure 20.36 Horizontal smile/chin ptosis phenomenon.

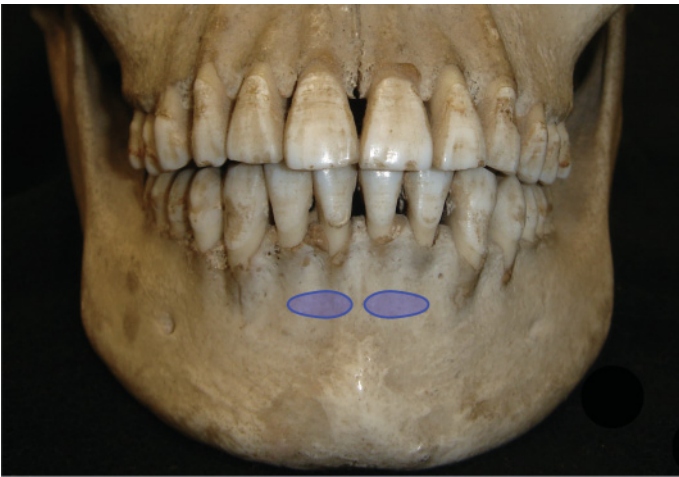


Figure 20.37 The mentalis origin is almost circular and relatively compact, just below the labial sulcus, arising from the anterior mandible at the level of and below the incisor roots, and *not from the pogonion*.

Mentalis muscle – anatomy, activity and significance

Zide and McCarthy (1989)⁴³ have described the mentalis muscle as ‘an essential component of chin and lower lip position’. The mentalis is required for normal activity of the central part of the lower lip and the position of the soft tissue chin pad.

Anatomy

The mentalis muscles are paired in the midline, separated from each other by a firm septum. The mentalis origin is almost circular and relatively compact, just below the labial sulcus, arising from the anterior mandible at the level of and below the incisor roots, and *not from the pogonion* (Figure 20.37). Zide and Boutros⁴² have explained that although when the lower lip is

pulled down it appears that the mentalis is attached approximately 10 mm below the attached gingivae, if the mentalis contracts, its attachment may be seen just below the attached gingivae, about 4–5 mm below the mandibular incisor gingival margins. The mentalis fibres pass *downwards and forwards*, fanning out to insert into the skin of the chin directly at the soft tissue prominence. The superior fibres are shortest in length and may course almost horizontally, *inserting just below the mentolabial fold*. The inferior and longest fibres course obliquely downwards, and may be almost vertical. The depth of the lower anterior labial sulcus is determined by the attachment of the superior mentalis fibres to the anterior part of the mandible. The width of the muscle may be palpated in this region and the sulcus depth drops at the level of the canines. A finger placed at the midsulcus will be forced upwards by mentalis contraction. Contraction of the mentalis forces the skin of the chin against the anterior aspect of the mandible. As the muscle direction is primarily downward, the indirect effect is to *elevate the lower lip*; indirect because no mentalis fibres enter the lower lip (Figure 20.38).

Note

The cleft chin: The paired mentalis muscles originate separately just below the mucosa of the lower labial sulcus; the superior most point of origin is just below the attached gingivae. The muscles sweep downward and forward, gradually fusing. The centre has the greatest overlapping muscle confluence, tapering out gradually to each side. In certain individuals the muscles do not overlap in the centre, but meet primarily in the upper or lower portions, or both (Figure 20.39). If the muscles do not meet at all centrally, a full central chin pad cleft occurs. If they meet primarily superiorly, the cleft is low; conversely, if the meeting is inferior, the cleft will be high. When palpating, the chin pad is thin in the area of the cleft, which is a muscle-free zone.⁴²



Figure 20.38 Contraction of the mentalis forces the skin of the chin against the anterior aspect of the mandible; the indirect effect is to elevate the lower lip.



Figure 20.39 Cleft chin.

Clinical significance

Patients with increased lower anterior face height and/or short lips may have an incomplete lip seal (incompetent lip posture). Almost continuous contraction and overactivity of the mentalis due to the patients attempt at maintaining a lip seal may lead to *hypertrophy* of the muscle, resulting in a 'knobbly' or 'bunching' appearance of the chin, and/or unattractive surface *corrugations*, described as uneven and irregular 'wrinkling' or 'dimpling' of the skin of the chin over the mentalis insertion, caused by the pull on the skin from the underlying muscle insertions (Figure 20.40). Identical dimpling may be noted in individuals with normal face height when pouting.

Reduced activity and hypotonia of the mentalis may be associated with a thick flaccid lower lip or severe mandibular dentoalveolar protrusion and/or proclination; it may also be a result of poor surgical technique.

Note

In patients with an incomplete lip seal (incompetent lip posture), there is almost constant hyperactivity of the mentalis muscle, often resulting in hypertrophy of the muscle. Following orthodontic treatment and/or orthognathic surgery and the achievement of a competent lip posture, the mentalis muscle may atrophy and, anecdotally, the soft tissue chin pad may move back up to 20–25%. Such potential posterior *soft tissue* chin movement should be planned in the anterior *skeletal* movement.

Patients with excessive chin prominence due to horizontal osseous macrogenia may require chin reduction genioplasty. This may produce **iatrogenic** problems:

- **Mentalis elongation:** This may occur in patients who have had burring of the anterior symphysis, symphyseal setback with overaggressive soft tissue dissection, or removal of excessively large chin implants (Figure 20.41A).⁴²
- **Inferior displacement of mentalis origin:** This may occur as a result of improper or omitted resuturing of the mentalis origin, leading to lip incompetence and possibly drooling.⁴² Brennan and Giammanco⁴⁴ noted that the 'ptotic chin syndrome', as seen after reduction genioplasty, may be due to the 'detachment and lower reattachment of the mentalis muscle' (Figure 20.41B).
- **Mentalis deficit:** Partial or total resection of the mentalis will prevent lip competence and may lead to drooling.⁴²

Reduced function of the mentalis will lead to lip incompetence, unattractive visibility of the mandibular incisors at rest and possibly drooling.

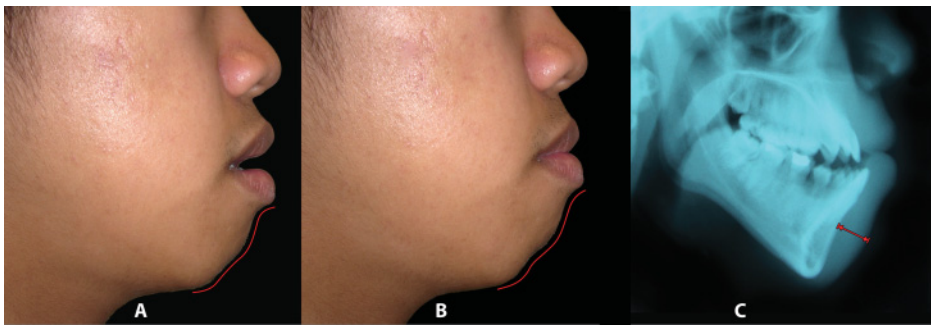


Figure 20.40 (A) Mentalis hypertrophy is evident in a patient with an incomplete lip seal (incompetent lip posture). (B) Lip strain to maintain a lip seal, with obvious contraction and hypertrophy of the mentalis. (C) Mentalis hypertrophy evident on lateral cephalometric radiograph.

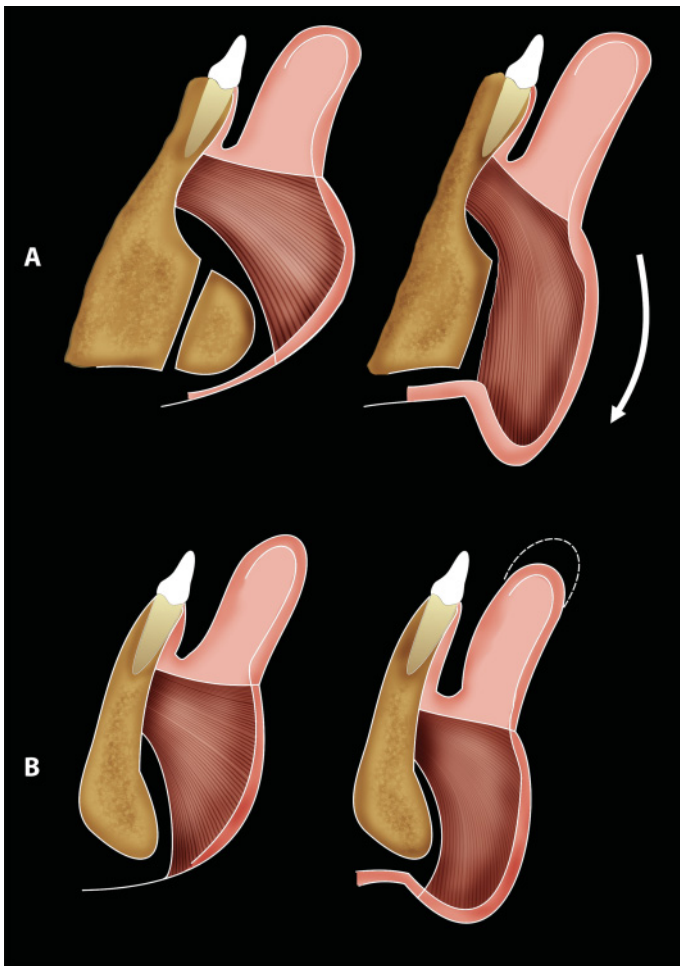


Figure 20.41 (A) Mentalis elongation: the mechanism of chin ptosis that may occur following excessive soft tissue dissection and bony burring for horizontal reduction genioplasty. (B) Inferior displacement of mentalis origin: the mechanism of chin ptosis, incompetent lip posture and deepening of the lower labial sulcus that may occur with inferior displacement of the mentalis origin as a result of improper or omitted resuturing of the mentalis origin. (Modified from Zide and McCarthy,⁴³ with kind permission of Wolters Kluwer Health.)

Note

Advancement genioplasty tends to have more predictable results than reduction genioplasty. The appearance of the soft tissue chin after reduction genioplasty has been described as resembling a 'partially deflated soccer ball'. Hohl and Epker⁴⁵ have advised that in order to achieve predictable soft tissue chin pad aesthetic results the symphysis *must not be degloved* with reduction genioplasty; the actual removal of bone must be done between the apices of the teeth and the inferior part of the symphysis.

In certain situations, clockwise rotation of the maxillo-mandibular complex (in the direction of mouth opening) may be used to reduce the chin prominence and thereby avoid the need for chin reduction surgery.

Vertical chin height

Proportional relationships

The lower facial third may be vertically divided into equal thirds by transverse lines passing through subnasale, stomion, the deepest point of the mentolabial groove, and soft tissue menton. Equal halves may be established by transverse lines passing through subnasale, the vermillion border of the lower lip and soft tissue menton (see Figures 9.12 and 9.14).

Mandibular anterior dental height

This is the distance from the incisal edge of the mandibular incisor teeth to menton (see Figure 7.49). The normal values are:

- Male: UK 40 ± 3 mm;³⁰ US 49 ± 3 mm.³¹
- Female: UK 38 ± 3 mm;³⁰ US: 42 ± 3 mm.³¹

Although this measurement is useful in evaluating the vertical skeletal chin height, it does depend on the inclination and vertical eruptive position of the mandibular incisor teeth. The normal eruptive position of the mandibular incisors may be impeded by a forward resting tongue position, which contributes to the formation of an anterior open bite. Conversely, an individual with a moderate to severe Class II skeletal pattern or an increased lower anterior face height and normal tongue

position/function may have overeruption of the mandibular incisor teeth.

The management of increased vertical chin height usually centres on vertical reduction genioplasty.

Transverse chin width

Assessment of chin symmetry and asymmetry has been described in Chapter 19. The width of the chin is variable. In frontal view, the transition of the lower border of the mandible from the gonial angles, along the lower border to the chin anteriorly follows a relatively smooth contour in women, ending in a **single light reflection**.¹¹ There is greater angularity in men both at the gonial angles and the transition between the lower border of the mandible and the chin, ending in a **double light reflection**, which indicates wider and more rectangular chin morphology.

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Chapter 21 Submental-Cervical Region

Introduction

The morphology of the upper aspect of the neck and its transition with the submental region has a major impact on the aesthetics of the lower face.

Anatomy

The anterior part of the neck extends no higher than the inferior border of the mandible. The **hyoid bone** is connected to the mandible by a thin sheet of muscle, the mylohyoids, which form the upper limit of the anterior part of the neck and separate the mouth from the neck. Superficially (i.e. below the mylohyoids) lies the **anterior belly of digastric**, while lying above it, half hidden under the mandible in the submandibular fossa, is the **submandibular salivary gland** (Figure 21.1). These structures are covered in by the investing layer of deep cervical fascia, which is attached to the hyoid bone and the inferior border of the mandible.

The **platysma** muscle lies in the subcutaneous tissues. It forms a broad, flat sheet, extending from the deep fascia over the upper part of pectoralis major and the most anterior part of deltoid to the inferior border of the mandible, with some fibres reaching the lateral part of the lower lip.

The **sternocleidomastoid** muscle forms a prominent neck landmark and may be made to stand out by turning the head towards the opposite side against resistance. The two heads of origin are from the sternum and medial one-third of the clavicle; its attachment is to the mastoid process, which forms a readily visible and palpable bony landmark behind the lobe of the ear (Figure 21.2).

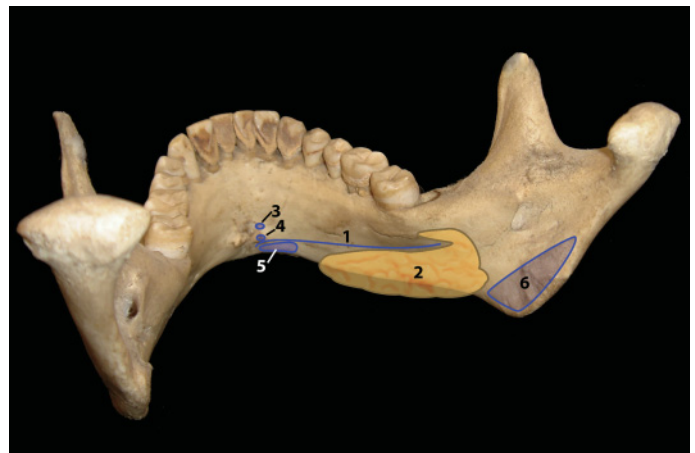


Figure 21.1 Submental anatomy in relation to the mandible, with muscle attachments:

- 1 Mylohyoid muscle
- 2 Submandibular salivary gland
- 3 Genioglossus muscle
- 4 Geniohyoid muscle
- 5 Anterior belly of digastric muscle
- 6 Medial pterygoid muscle

Terminology

Despite its importance in facial aesthetics, there is *much confusion in terminology* relating to the description and analysis of the submental-cervical region. For example, the cervicomental angle has been described by perhaps half a dozen different methods,

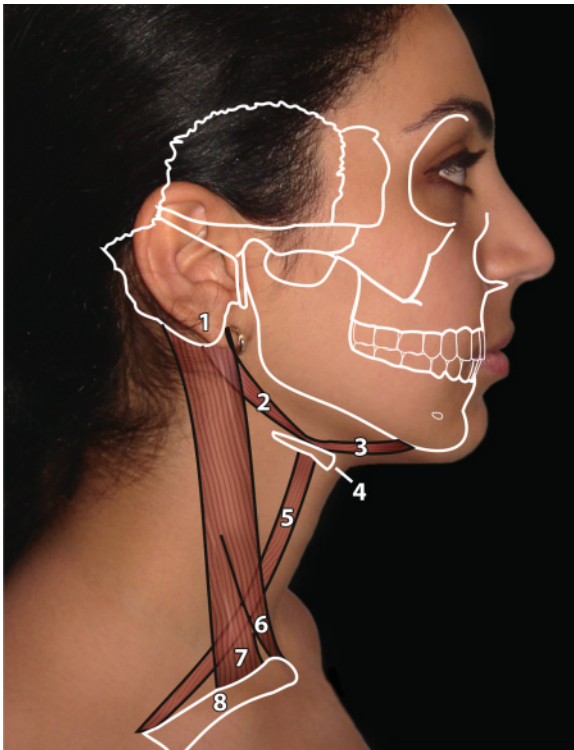


Figure 21.2 Profile view of the face and neck with superimposed bony and muscular outlines:

- 1 Mastoid process
- 2 Posterior belly of digastric muscle
- 3 Anterior belly of digastric muscle
- 4 Hyoid bone
- 5 Omohyoid muscle
- 6 Sternocleidomastoid muscle – sternal head
- 7 Sternocleidomastoid muscle – clavicular head
- 8 Clavicle

depending on the describing authority. Appropriate terminology is essential for the evaluation and accurate description of submental-cervical aesthetics (Figure 21.3).

Cervical point (C-point or 'point C'): The innermost (posterior-superior) point between the submental plane and the anterior aspect of the neck in the midsagittal plane, located at the intersection of lines drawn tangent to the submental region and the anterior neck.

Submental plane: A plane or line constructed between the cervical point (C-point) and the most inferior point on the chin (soft tissue menton, Me'). If C-point cannot be defined, the submental plane is drawn tangent to the submental contour passing through soft tissue menton. The submental plane is referred to as the 'throat' plane by some authorities; the **submental length** (distance from C-point to menton) is therefore sometimes referred to as the 'throat length'.

Cervical plane: A plane or line drawn tangent to the anterior soft tissue contour of the neck above and below the thyroid prominence.

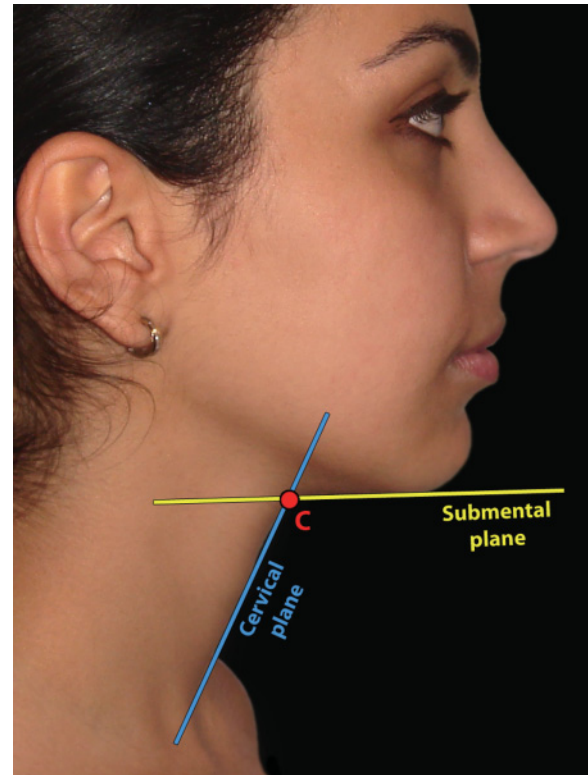


Figure 21.3 Submental plane, cervical plane and cervical point (C-point).

- Cranial (from Greek *kranion*: the upper part of the head).
- Cephalic (from Greek *kephale*: head).
- Cervical (from modern Latin *cervicalis*; from Latin *cervix*: neck).
- Caudal (from Latin *cauda*: a tail).
- Supra- (prefix Latin: above).
- Sub- (prefix Latin: under, below).
- Hyoid (Greek letter upsilon, υ , and -oid, i.e. U-shaped).

Aetiology

A thorough understanding of the aetiological factors involved in creating a poor aesthetic contour of the submental-cervical region is required in order to diagnose and appropriately plan the correction of the aesthetic submental-cervical angles and contour. The tonicity of the submental-cervical skin, the muscular support of the neck, the isolated fatty deposits in the submental-cervical region, the skeletal framework of the mandible and chin, and the spatial position of the hyoid bone are all important parameters in the aesthetic analysis of the submental-cervical region.

Aetiology of poor submental-cervical contour

An undesirable submental-cervical contour may result from:

- Excessive, flaccid skin.

- Excess fat:
 - Submental
 - Supraplatysmal
 - Subplatysmal.

Note

The excess fat leading to an undesirable submental-cervical contour is often composed of localized adipose deposits that are out of proportion to the remainder of the patient's body, which will not adequately diminish with exercise and diet.

- Flaccid, ptotic platysma; prominent platysmal bands.
- Large submandibular glands.
- Mandibular/chin deficiency in the sagittal plane: This is due to a reduced submental length (C-point to soft tissue menton distance). Mandibular advancement and/or forward sliding genioplasty improve the submental-cervical contour, whereas mandibular setback worsens it.
- Posterior (downward and backward) mandibular rotation secondary to vertical maxillary excess: Maxillary impaction will permit upward and forward autorotation of the mandible, thereby improving the submental-cervical contour.
- Hyoid bone position and suprahyoid muscle anatomy.
- Any combination of the above.

Clinical evaluation

It is paramount that the clinical evaluation is undertaken with the patient in natural head position (NHP). Even a small degree of upward or downward tilting of the head must be avoided as it may have a profound effect on the contour of the submental-cervical region. A number of parameters may be analysed in the clinical evaluation of the submental-cervical region:

- Skeletal pattern (jaw relationship).
- Morphology of the submental soft tissues:

- Laxity of the submental soft tissues
- Submental adiposity (fat accumulation)
- Inferior border of the mandible
- Submandibular gland position.
- Submental-facial angle.
- Submental length.
- Submental-neck (submental-cervical) angle.
- Submental-sternomastoid (SM-SM) angle.
- Submental soft tissue thickness.
- Hyoid bone position.

Note

The term **cervicomentale angle** (or mentocervical angle) has been described by different authorities as pertaining to the angular relationship between different parameters. For example, it has been described as the angle between the submental plane and the face, and also as the angle between the submental plane and the anterior neck cervical plane. Therefore, it is important to define the term when it is to be used.

Skeletal pattern (jaw relationship)

Mandibular and/or chin deficiency in the sagittal plane, and/or posterior (downward and backward) rotation of the mandible, often secondary to vertical maxillary excess, may contribute to the undesirable aesthetic appearance of the submental-cervical region (Figure 21.4). It is helpful to have the 'Class II skeletal pattern' patient *posture the mandible forward to a more normal sagittal position*, which will concurrently stretch the submental soft tissues. If this manoeuvre improves the submental-cervical aesthetics visually, and tightens the submental soft tissues to palpation, then correction of the underlying skeletal discrepancy is likely to improve the submental-cervical aesthetics (Figure 21.5).

The converse is also true. Surgical procedures to set back the mandible, or set down the maxilla causing posterior mandibular



Figure 21.4 Class II jaw relationship due to mandibular deficiency and significant compensatory proclination of the mandibular incisor teeth; the submental-cervical angle is increased.

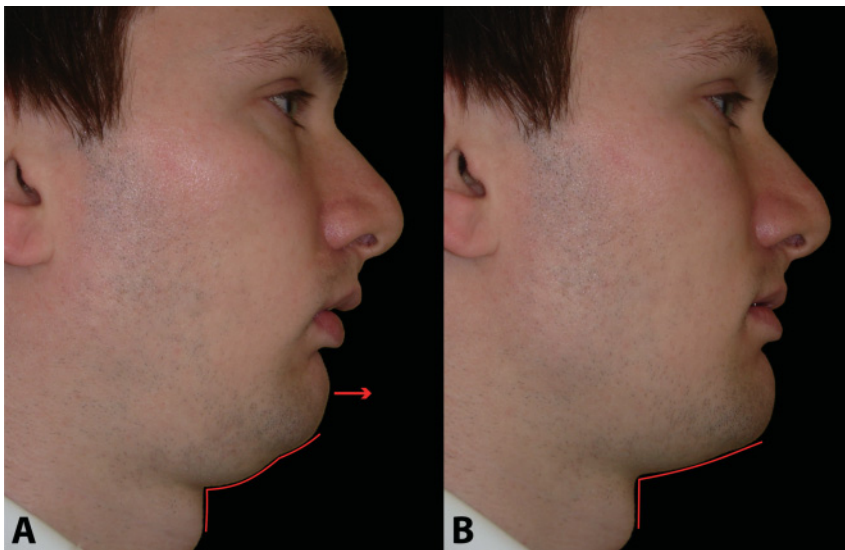


Figure 21.5 (A) Patient with Class II jaw relationship due to mandibular deficiency. (B) Posturing the mandible forward to a more normal sagittal position will concurrently stretch the submental soft tissues.



Figure 21.6 Skin laxity test.

rotation, will tend to have undesirable consequences on submental-cervical aesthetics (see Figure 19.22). The patient must be informed of these potential untoward consequences of orthognathic surgery, and should be advised of the possible future need for aesthetic surgical procedures of the submental-cervical region.

Morphology of the submental soft tissues

Laxity of the submental soft tissues

The laxity of the **submental-cervical skin** may be evaluated by the **skin laxity test**: the clinician stands behind the patient and gently pulls the soft tissues upward and backward just inferior and anterior to the ear, simulating a neck lift (Figure 21.6). If the soft tissues are easily displaced upward there is increased laxity of the skin, termed **redundant skin**.¹ If following this manoeuvre there is still submental fullness, the patient has redundant skin and excessive submental-cervical adiposity.

Reduced tonicity of the platysma may contribute significantly to submental fullness.^{2,3} In addition, the platysma muscle may or may not merge anatomically across the midline. Frequently, excessive submental fullness results not only from redundant skin but from the redundant medial borders of the platysma that fail to meet in the midline.

Note

An important photographic view that may aid the clinician in evaluating the role of the platysma in submental-cervical deformities is the frontal full face taken with the head slightly tilted backwards and the teeth clenched to contract the platysma muscle, termed the 'platysma view' (Figure 21.7).³ Prominent platysma borders and **platysmal bands** may be identified and indicated to the patient. Platysmal bands may also be evident in the ageing neck (Figure 21.8).

Submental adiposity (fat accumulation)

Increased submental-cervical fat accumulation may be independent of generalized body fat; in some patients subcutaneous fat accumulation in this region may remain despite extensive weight loss. In younger patients the fat usually accumulates between the skin and the platysma muscle. In older patients the fat may accumulate both deep and superficial to the platysma (Figure 21.9).

The quantity of submental fat may be estimated by the **submental pinch test**: the submental soft tissues are gently gripped between the thumb and index finger.¹ This manoeuvre should be



Figure 21.7 Platysma view: With the head tilted slightly back in frontal view, grimacing and clenching the teeth will induce contraction of the platysma muscle. The muscular fascicles of the platysma become visible beneath the skin.



Figure 21.9 Submental adiposity.



Figure 21.8 Platysmal bands may be evident in repose in an ageing neck.

performed with the patient in natural head position as well as with the head extended and contracting the platysma muscle; in this way the clinician can determine whether the submental fat is predominantly supraplatysmal or subplatysmal.

Inferior border of the mandible

The definition of the inferior border of the mandible, from the chin to the gonial angle, is an important aesthetic parameter, as it *defines the demarcation between the face and neck* (Figure 21.10). In frontal view, the transition from the upper aspect of the neck to the inferior border of the mandible has a subtle hourglass appearance, with its superior aspect being well defined



Figure 21.10 The definition of the inferior border of the mandible is an important aesthetic parameter as it defines the demarcation between the face and neck. (Detail, *Woman's Head*, Leonardo da Vinci, c. 1470–76, Galleria degli Uffizi, Florence.)

by the concavity immediately below the inferior mandibular borders (Figure 21.11).¹ The soft tissues of the neck normally closely adhere to the structures underlying them. Lack of definition of the inferior mandibular border may be due to increased soft tissue laxity, fat accumulation, mandibular/chin deficiency or hyoid bone sag.



Figure 21.11 In frontal view, the transition from the upper aspect of the neck to the inferior border of the mandible has a subtle hourglass appearance.

Submandibular gland position

The submandibular salivary gland envelopes the posterior border of the mylohyoid muscle, half hidden in the submandibular fossa on the medial aspect of the mandible (Figure 21.1). Submandibular fullness may result from an increase in size of the submandibular gland, laxity of the neck fascial layer or submandibular gland ptosis. Rhytidectomy and platysma plication address this problem indirectly by increasing the fascial support for the gland. However, patients may develop a more noticeable submandibular fullness as the removal of submental fat unmasks the ptotic gland.

Partial or complete submandibular gland resection provides definite improvement of submandibular fullness resulting from glandular hypertrophy or ptosis, but may be considered too radical for a patient with a normal sized, ptotic submandibular gland. Guyuron et al.⁴ have described the **basket submandibular**

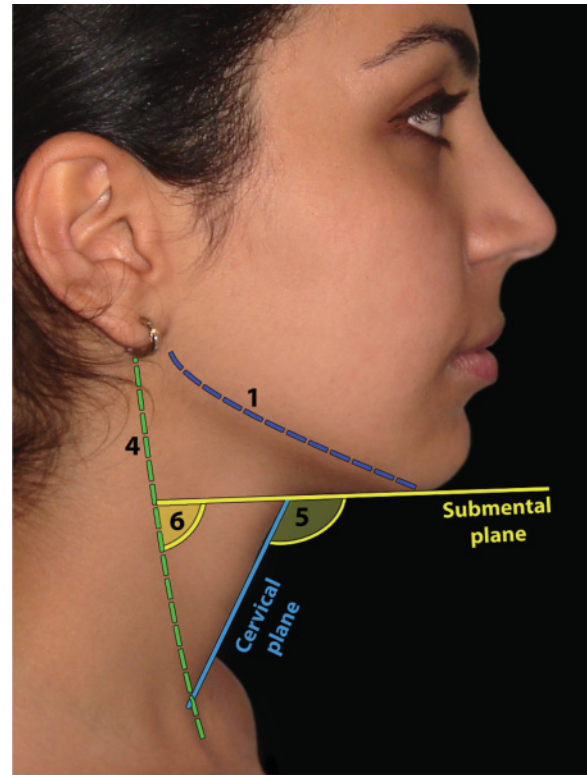


Figure 21.12 Of the 'six visual criteria' of the profile view for 'success in restoring the youthful neck', the following are demonstrated:

- 1 Distinct inferior mandibular border
- 4 Visible anterior border of sternocleidomastoid muscle
- 5 Submental-cervical (submental-neck) angle between 105° and 120°
- 6 Sternocleidomastoid-submental plane (SM-SM) angle approximately 90°

gland suspension technique, directly supporting the gland onto the inner aspect of the inferior surface of the mandible with a strong piece of fascia. This technique helps eliminate submandibular fullness in patients with normal sized, ptotic glands. Resection remains the treatment of choice for the correction of glandular hypertrophy.

Note

Ellenbogen and Karlin⁵ described **six visual criteria** of the profile view for 'success in restoring the youthful neck', from evaluation of the submental-cervical region in their post-operative female rhytidectomy patients (Figure 21.12):

1. **Inferior mandibular border:** Distinct inferior mandibular border from chin to gonial angle with no jowl overhang.
2. **Subhyoid depression:** Without this slight depression just inferior to C-point, the neck does not give the appearance of being thin and long.
3. **Thyroid cartilage:** Visible thyroid cartilage prominence. The most obvious palpable feature in the front of the neck below the hyoid bone is the midline subcutaneous laryngeal prominence of the thyroid cartilage, also termed the

Adam's apple. In the male, this prominence is usually clearly visible, whereas in the female it is not usually apparent, even in profile view.

4. **Sternocleidomastoid muscle:** Visible anterior border of sternocleidomastoid muscle distinct in its entire course from the mastoid to the sternum. They felt this to be the least important criterion to be met.
5. **Submental-neck angle** (referred to as the cervicomental angle) between 105° and 120°. An angle greater than 120° gives the visual impression of a 'double chin' or 'heavy neck'.
6. **Sternocleidomastoid-submental plane angle (SM-SM angle).** This angle should approximate 90° in the 'youthful neck'.

These criteria may be determined by visual inspection of the profile view. The two most important criteria are the *distinct inferior mandibular border* and the *submental-neck angle*.

Submental-facial angle

The submental-facial angle is formed by the intersection of the submental plane and the face in profile view. The 'facial' aspect of the angle may be determined in relation to different facial structures (Figure 21.13):

- **Submental plane to facial plane:** This angle may be determined by constructing the submental plane to intersect the facial plane (glabella to soft tissue pogonion). According to Powell and Humphreys, this 'mentocervical angle' should be in the range:⁶
 - 80–95°.
- **Submental plane to lower facial plane:** This angle was described by Legan and Burstone (1980)⁷ and termed the **lower face-throat angle**. The angle is measured by the intersection of C-point to soft tissue menton (described as 'gnathion' in the original article)⁷ and the lower facial plane (subnasale to soft tissue pogonion).
 - Average: $100^\circ \pm 7^\circ$.
- **Submental plane to chin tangent:** Anthropometric measurements by Farkas⁸ measured the 'cervicomental angle' between the submental plane and a tangent to the anterior aspect of the chin. Normal values were:
 - Male: $78^\circ \pm 8^\circ$.
 - Female: $84^\circ \pm 9^\circ$.
- **Lower lip-chin-submental plane angle:** This angle, also known as the **lower lip-chin-throat angle**, is formed by the intersection of a line drawn from Li (labrale inferioris) to soft tissue pogonion (Pog') and the submental plane. This angle will also vary depending on the sagittal prominence of the lower lip.⁹
 - Average: $110^\circ \pm 8^\circ$.
- **Submental plane to E-line:** Determined by the intersection of the submental plane and the Ricketts E-line.
 - Average: $115^\circ \pm 5^\circ$.
- **Submental plane to SnV:** Determined by the intersection of the submental plane and a vertical plane through subnasale (SnV), with the patient in NHP.¹⁰
 - Average: $94^\circ \pm 5^\circ$ (range 84–105°).

Note

The 'ideal' measurement may be taken from the intersection of the submental plane (C-point to Me') with a **true vertical plane** through soft tissue pogonion. This will negate the influence of the prominence of the upper facial structures on this angular measurement. The 'ideal' angle should be approximately 90° (range 85–100°). It is also possible to assess the intersection of the submental plane with a **true horizontal plane** through soft tissue menton. The ideal inclination of the submental plane should be approximately parallel to the true horizontal plane (Figure 21.14).

Submental length

The submental length is measured as the distance from C-point to soft tissue menton with the patient's head in natural head position. This distance may also be measured from C-point to a tangent to soft tissue pogonion.

- **Absolute linear distance:** Different authorities have provided a number of 'normal' values for submental length (Figure 21.15):
 - 57 ± 6 mm; C-point to menton⁹
 - 62 ± 6 mm; C-point to pogonion tangent¹⁰
 - 51 mm (range 32–73 mm); C-point to tangent to a line joining subnasale and pogonion¹¹
 - 50 mm; C-point to pogonion tangent¹.
- **Proportional relationship:**
 - **Submental length to orbital depth** (Figure 21.16): This proportional relationship is evident in the drawings of Leonardo da Vinci. The submental length is approximately equal to twice the depth from nasion to the lateral canthus of the eye in profile view, and 1:1 to orbital depth.
 - **Submental length to lower lip-chin height** (Figure 21.16): Leonardo da Vinci described 'ideal' submental length as equal to the distance between the mouth (stomion) and the bottom of the chin (menton), which is a quarter of the face height.^{12,13}

Farkas⁸ found the following values for lower lip-chin height (stomion-menton):

 - Male: 50 ± 4 mm
 - Female: 45 ± 3 mm.
 - **Lower vertical height-depth ratio:** Legan and Burstone⁷ described the proportional relationship between lower face height and depth, termed the lower vertical height-depth ratio (Figure 21.17):
 - $\text{Sn-Me}'/\text{C-Pog}' = 1.2$ (i.e. for the same lower face height, a ratio greater than 1.2 relates to a reduced submental length).

Note

The submental length tends to be reduced in patients with true mandibular deficiency and increased in those with true mandibular excess. A mandibular advancement will tend to increase the submental length, which is usually an aesthetic improvement (see Figure 20.29). Conversely, a mandibular setback will reduce the submental length and lead to increased 'submental fullness', which is undesirable (see Figure 19.22). Mandibular setback procedures should be avoided in patients with a significantly reduced submental length.

Submental-neck (submental-cervical) angle

The submental-neck angle (or 'cervicomental angle') helps to describe the contour of the transition from the submental plane to the anterior aspect of the neck. This angle makes



Figure 21.13 (A and B) Submental-facial angles – methods of evaluation.

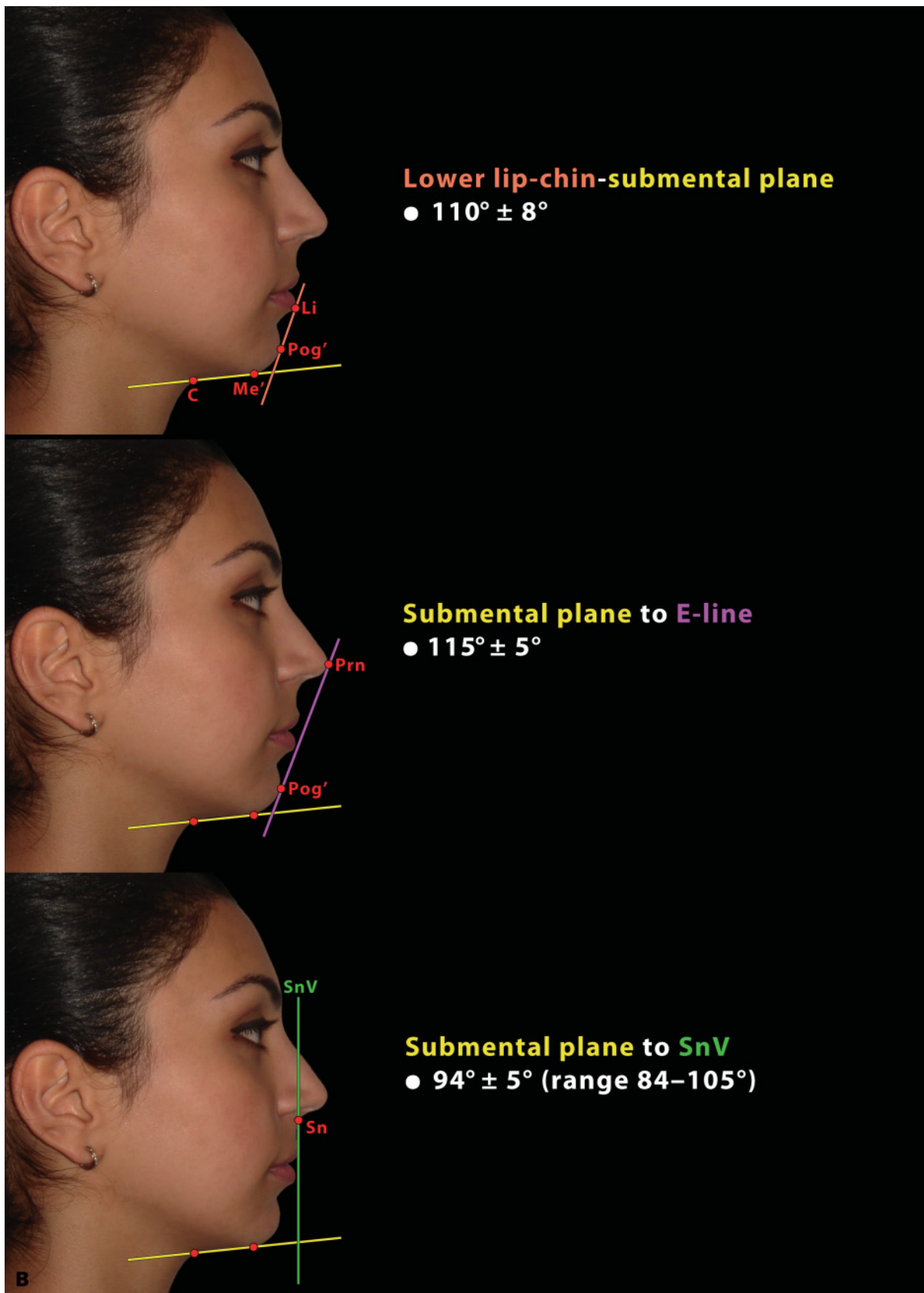


Figure 21.13 Continued

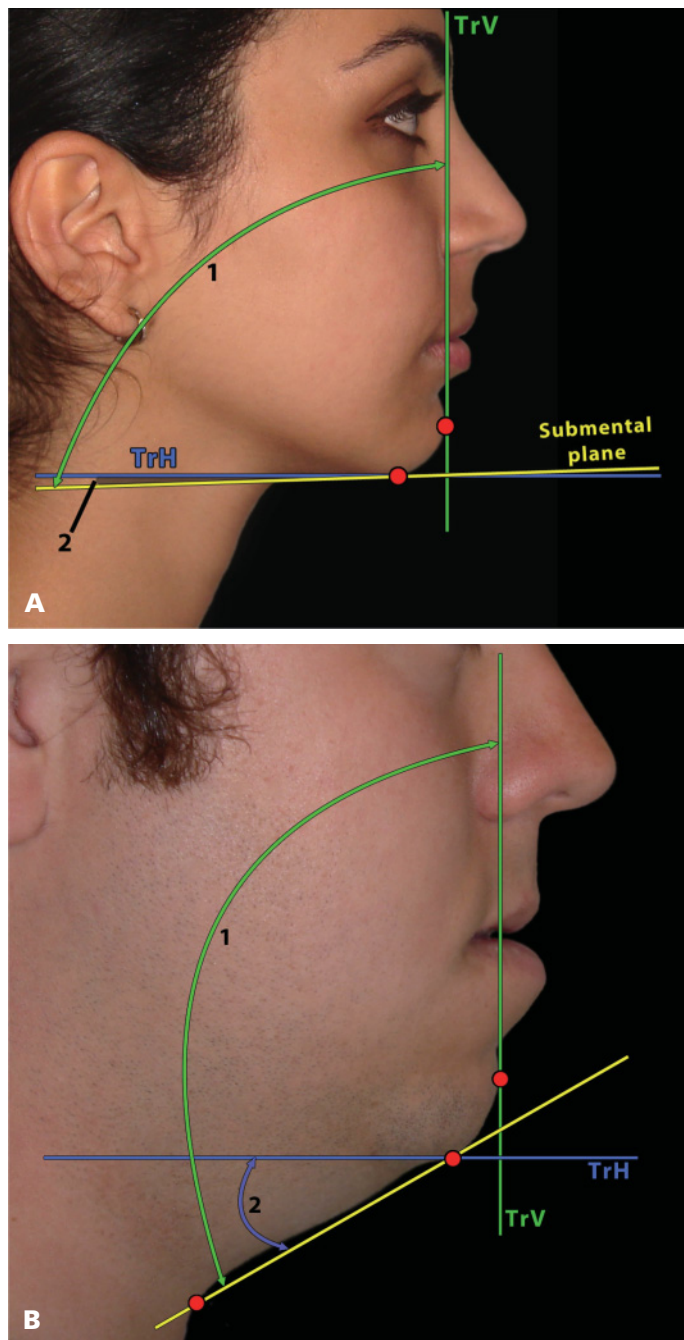


Figure 21.14 (A and B) Inclination of the submental plane to the true vertical plane (TrV) and true horizontal plane (TrH).

a significant contribution to submental-cervical aesthetics (Figure 21.18).

- The 'ideal' angle is approximately 110° .¹
- The average values provided by Sommerville et al.¹¹ are:
 - Male: 126°
 - Female: 121° .
- The average value provided by Moreno et al.¹⁰ is:
 - $118^\circ \pm 8^\circ$ (range 100–135°).

Note

It appears that the often described 'ideal' 90° submental-cervical angle appears to be an extreme of the normal variation.

Submental-sternomastoid (SM-SM) angle

The angle formed between the submental plane and the visible anterior border of the sternocleidomastoid muscle should approximate 90° (Figure 21.12).⁵ This is not deemed as important as the two 'important' criteria, i.e. distinct inferior mandibular border and submental-neck angle between 105° and 120° .

Submental soft tissue thickness

Moreno et al.¹⁰ described a method to quantify the submental soft tissue thickness through cephalometric parameters. Submental thickness measurements may be determined from lateral cephalometric radiographs taken with the patient in natural head position, by measuring the thickness at various points on the submental plane from the inferior border of the mandible. This method may be useful in comparing pre- and post-surgical changes in the submental soft tissue thickness. Moreno et al.¹⁰ described the following normative values (Figure 21.19):

- **Me-Me'** (vertical distance between skeletal menton and soft tissue menton):
 - 8 ± 1 mm (range: 6–9 mm).
- **IBM-Sm'** (distance between the inferior border of the mandible and the submental plane, measured on the orbitale vertical, OrV line):
 - 13 ± 4 mm (range: 6–20 mm).
- **IBM-Sm''** (vertical distance between submental plane and the point that is the intersection of the mandibular inferior border and the line bisecting sella-C-submental plane angle):
 - 17 ± 3 mm (range: 10–22 mm).
- **IBM-C** (distance between the inferior border of the mandible and the submental plane, measured on the sella-point C line):
 - 28 ± 6 mm (range: 17–37 mm).

Hyoid bone position and submental-cervical aesthetics

The sagittal and vertical position of the hyoid bone and the anatomy of the suprahyoid muscles play an important role in the morphology of the **submental-cervical** region.

Marino et al.¹⁴ described the importance of the position of the hyoid bone in patients with poor submental-cervical contour with an obtuse submental-neck angle, but did not offer any solutions for correction when the hyoid bone was the main contributing factor. Collins and Epker¹⁵ suggested performing a suprahyoid myotomy during a genioplasty in order to improve the submental-neck angle. Guyuron¹⁶ found that the more

Figure 21.15 Submental length may be measured from C-point to soft tissue menton or to a line tangent to soft tissue pogonion. (A) Reduced submental length. (B) Increased submental length.

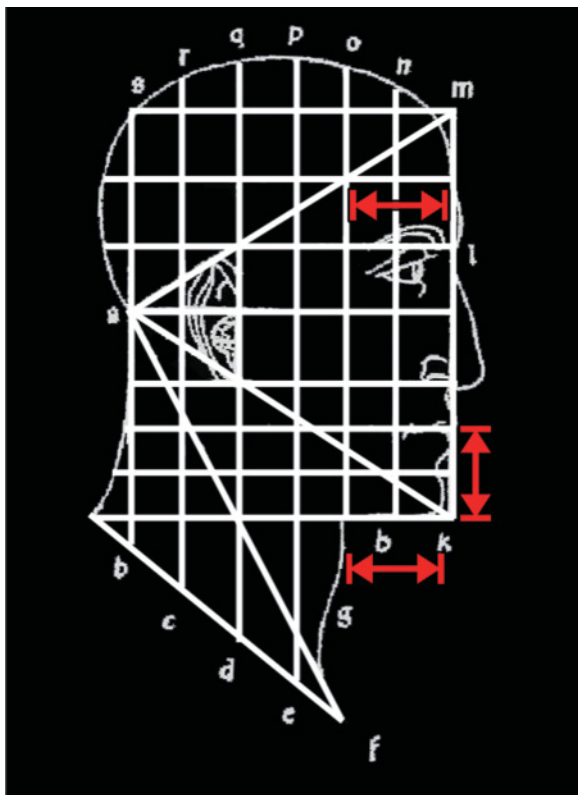
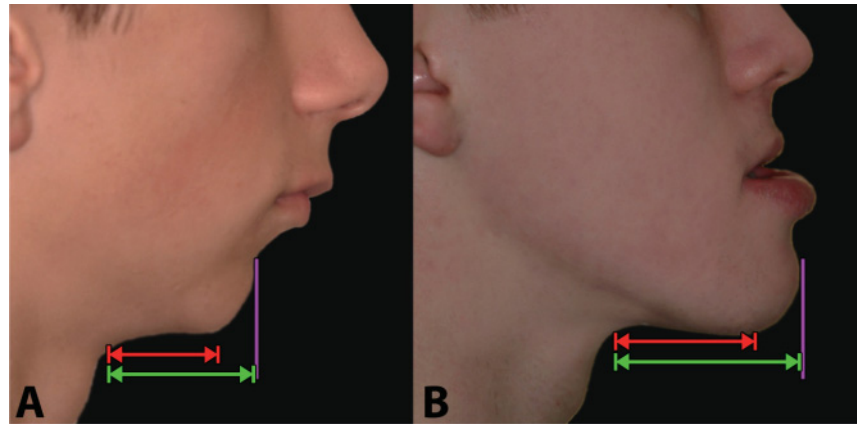


Figure 21.16 Submental length to orbital depth (1:1) and submental length to lower lip-chin height (1:1) (Redrawn and modified from Leonardo da Vinci, in Luca Pacioli's *De Divina Proportione*, 1494; see Chapter 2.)

superior and posterior the position of the hyoid bone, the better defined and narrower the submental-neck angle.

Anatomy

The spatial position of the U-shaped hyoid bone and its attached muscles is important in the aesthetics of the submental-cervical region. The hyoid bone may be palpated between finger and thumb a few centimetres below and behind the chin, especially if the neck is extended. Its relation to the inferior border of the mandible may be noted, though this is better assessed on a lateral

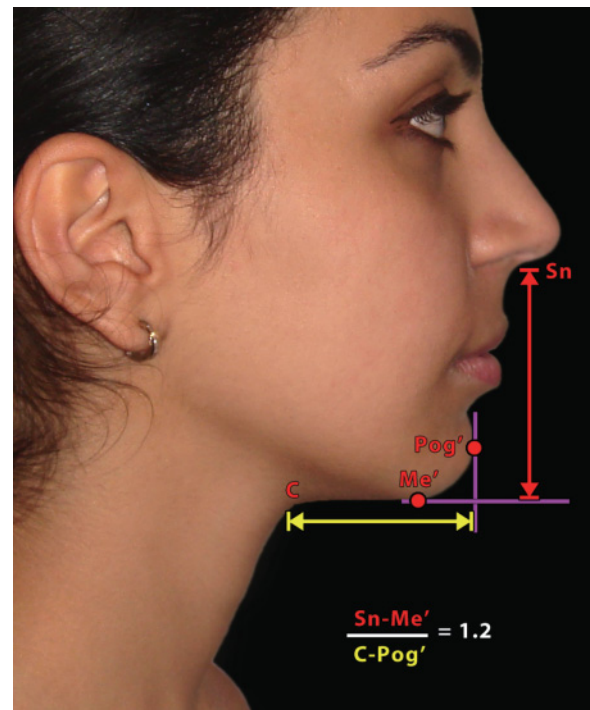


Figure 21.17 Lower vertical height-depth ratio.

cephalometric radiograph. Four muscles are important in the aesthetic anatomy of the submental-cervical region: the platysma, digastric, mylohyoid and geniohyoid. The anatomic plane between these muscles may not be clearly identifiable anteriorly, but the muscles are isolated and distinguishable posteriorly. It is important to note that above the hyoid bone the musculature runs in a predominantly horizontal or oblique direction (**suprahyoid muscles**), whereas below the hyoid it runs in a vertical direction (**infrahyoid muscles**).

Evaluation of hyoid bone position in normal attractive neck

The sagittal and vertical position of the hyoid bone may be evaluated on a lateral cephalometric radiograph taken with the patient in natural head position (Figure 21.20).

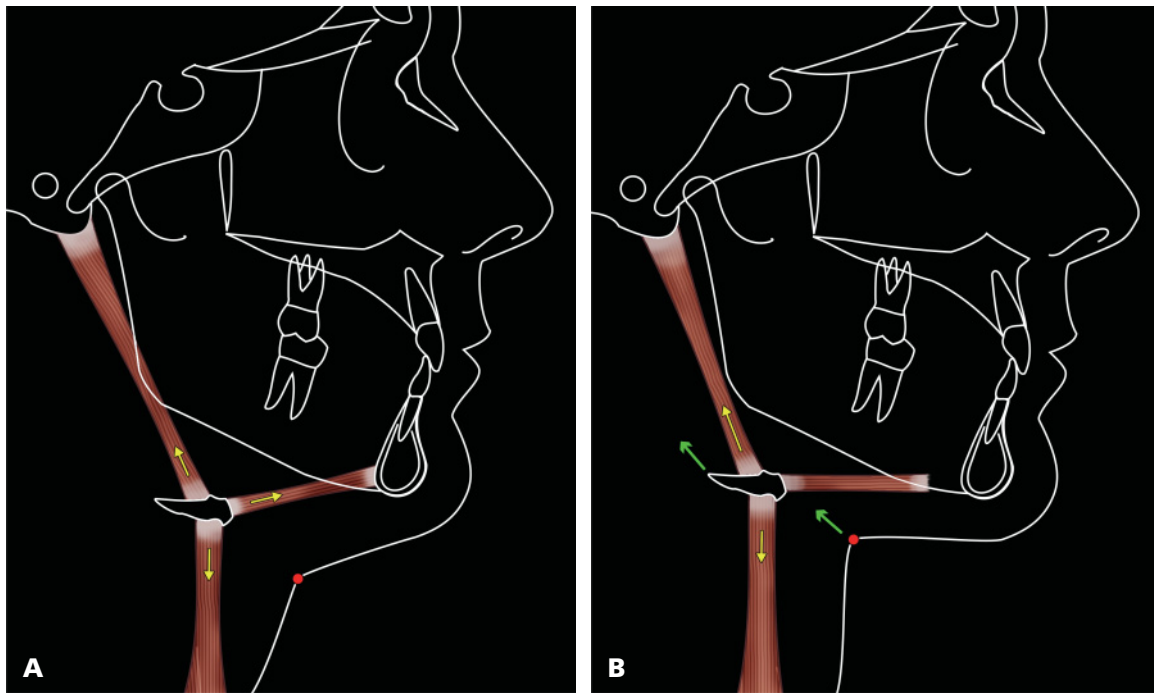


Figure 21.21 (A) Schematic diagram depicting an obtuse submental-cervical angle due to an excessively caudal and anterior hyoid bone position. (B) Submental suprahyoid myotomy permits posterior and cephalic relocation of the hyoid bone, reducing the submental-neck angle and improving the submental-cervical contour.

- Hy-FH: 48 ± 5 mm (range 41–58 mm).
- Hy-OrV: 84 ± 9 mm (range 68–95 mm).
- Hy – the most anterior-superior point of the greater horn of the hyoid bone.
- OrV – the orbitale vertical line; a line perpendicular to Frankfort Horizontal plane passing through orbitale point.

Muscular control of hyoid bone position

The position of the hyoid bone is controlled by three groups of muscles:

- **Anterior-superior movement of hyoid bone:** The anterior belly of the digastric, geniohyoid and mylohyoid muscles pull the hyoid bone superiorly and anteriorly.
- **Posterior-superior movement of hyoid bone:** The stylohyoid muscles pull the hyoid bone superiorly and posteriorly.
- **Inferior movement of hyoid bone:** The sternohyoid and omohyoid muscles pull the hyoid bone caudally.

Management

The majority of patients with ‘submental fullness’ or ‘fallen necks’ present with flaccid skin, excessive submental fat accumulation, a prominent and flaccid platysma and a *normal hyoid bone position*. Correction of this condition requires a neck lift (cutaneous correction, lipectomy and/or submental liposuction,

and platysmoplasty [platysmal plication]. However, in some patients the increased submental-neck angle is primarily due to an excessively low hyoid bone position. In such patients, a neck lift as described above cannot elevate the vertex of the submental-neck angle (cervical ‘C’-point) because of the low position of the hyoid bone; hence, isolated soft tissue aesthetic procedures in the neck will have limited results.

Guyuron¹⁶ has suggested that transection of the anterior suprahyoid muscles at their attachment to the posterior aspect of the mandible in patients with an obtuse submental-neck angle *due to caudal and anterior hyoid bone position* will allow posterior and cephalic relocation of the hyoid bone, reducing the submental-neck angle and improving the submental-cervical contour (Figure 21.21). The hyoid bone was found to move an average 5 mm (range 1–7 mm) superiorly and 4 mm (range 2–7 mm) posteriorly following **submental suprahyoid myotomy**. The technique is recommended for patients who have a reduced distance between the hyoid bone and the mandibular symphysis, or an excessively caudally positioned hyoid bone.

Relative submental projection and aesthetics

The morphology, size and position of the submental-cervical region must be evaluated both in isolation and relative to the rest of the facial profile. The anterior projection of the forehead, nose,



Figure 21.22 Identical facial profiles varying only in the submental-cervical contour; the submental-cervical contour may influence the perceived aesthetics of the other facial prominences (forehead, nose, lips and chin).

lips, chin and submental region form five important and inter-related facial prominences.

The submental-cervical contour may influence the perceived aesthetics of the other facial prominences (Figure 21.22). For example, Greer et al.¹⁷ (2001) found a strong nasal to cervical relationship, whereby the perceived appearance of the nose was affected by the contour of the neck.

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SECTION 4 Smile and Dentogingival Aesthetic Analysis

Introduction to Section 4

‘Tis the perception of the beautiful,
... Without which life would be extremely dull.’

Lord Byron (1788–1824), *Don Juan*, Canto II (1819)

The teeth and their supporting alveolar bone, together termed the maxillary and mandibular **dentoalveolar processes**, provide much of the *supporting framework over which the soft tissues of the lower face drape*, in particular the lips. They also provide much of the height of the lower face and thereby account for the proportional relationships of the lower face to the rest of the craniofacial complex; examination of an edentulous individual demonstrates the structural changes and concomitant reduction

in lower anterior face height that occur due to loss of the teeth and subsequent resorption of the alveolar processes.

The dentoalveolar complex is the vital element in the smile, which together with the eyes provide the most important facial parameters for facial expressions and non-verbal communication. The teeth also serve vital *functional roles* in incising food and mastication (chewing), deglutition (swallowing) and phonation (speech).

A smile may make or mar the beauty of a face. As such, analysis of the smile forms an important part of facial aesthetic evaluation.

‘If the “eyes are the windows to the soul”,
The true smile is the window to the heart.’

Chapter 22

Dental-Occlusal Relationships: Terminology, Description and Classification

Introduction

A thorough understanding of 'ideal' and normal functional dental-occlusal relationships, together with the relationship of the dentoalveolar complex to the craniofacial complex, is paramount for accurate facial aesthetic evaluation and subsequent clinical diagnosis.

Terminology

The description of the structural relationships of the teeth and the dental occlusion, as with the rest of the craniofacial complex, is impossible without an understanding of the specialized vocabulary.

Terms of description of tooth form

There are 20 teeth (10 per jaw) in the deciduous or primary dentition. There are 32 teeth (16 per jaw) in the complete permanent dentition. In both dentitions there are three basic tooth forms:

- **Incisiform:** These are cutting teeth, which have thin, blade-like crowns.
- **Caniniform:** These are piercing or tearing teeth, which have a single, robust, pointed, cone-shaped crown; canine teeth are sometimes termed 'cuspid' teeth.
- **Molariform:** These are grinding teeth, which possess a number of cusps on an otherwise flattened biting surface. Premolar teeth are sometimes termed 'bicuspid' teeth.

Other terms of description are:

- **Anatomical crown:** The portion of a natural tooth that extends coronal from the cementsoenamel junction (CEJ).

- **Clinical crown:** The portion of the tooth crown visible in the oral cavity, extending from the cusp tip or incisal edge to the free gingival margin.
- **Root:** The portion of a tooth apical to the cementsoenamel junction (CEJ) that is normally covered by cementum (**anatomical root**) and is attached via the periodontal ligament to the supporting alveolar bone (**clinical root**).
- **Cervical margin:** The junction of the anatomical crown and root.
- **Occlusal surface:** The biting surface of molars and premolars.
- **Incisal edge:** The cutting edge of the incisor crown.
- **Cusp:** A cone-shaped prominence on the crown of a tooth, forming the occlusal surface.
- **Cingulum:** A lingual/palatal lobe of some anterior teeth (incisors and canines) in the form of a convex protuberance on the cervical one-third of the lingual/palatal surface of the anatomical crown.
- **Marginal ridge:** A linear elevation on the mesial or distal edge of the occlusal surface of molariform teeth.
- **Fossa:** An anatomical depression in the occlusal surface of a tooth.
- **Fissure:** An anatomical cleft or groove between the cusps or ridges on the occlusal surface of a tooth.

Terms of direction in dental nomenclature

Basic dental directions may be described in terms of orientation in relation to the teeth. The following terms may be used to

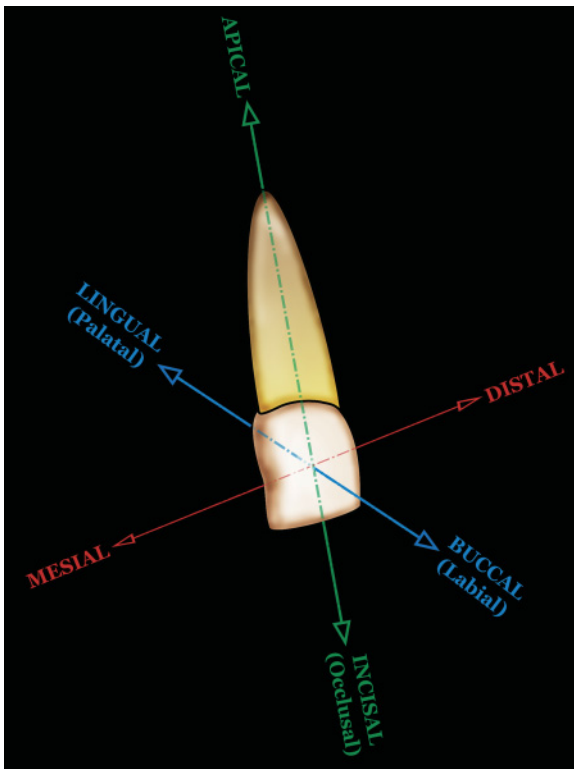


Figure 22.1 Terms of direction in dental nomenclature may be used to describe both the tooth crown surfaces and directions of tooth movement (a maxillary left central incisor is depicted).

describe both the tooth crown surfaces and directions of tooth movement (Figure 22.1):

- **Mesial:** This term means toward the dental midline, along the dental arch.
- **Distal:** This term means away from the dental midline, along the dental arch.
- **Buccal (labial):** This term means in the direction of the cheeks; it is ideally used for the posterior teeth but may be used as an inclusive term for both posterior and anterior teeth. The terms 'labial' or 'facial' mean in the direction of the lips; they are *only* used for the incisor teeth.
- **Lingual (palatal):** The term 'lingual' means in the direction of the tongue; it also refers to the tooth surface facing the tongue. The term 'palatal' may be used when referring to the maxillary dentition.
- **Apical:** This term means toward the root apex.
- **Occlusal (incisal):** The term 'occlusal' means in the direction of the masticatory surfaces of the teeth. The term 'incisal' is the equivalent for the incisor teeth.

Terms of tooth position in the three planes of space

The term **bodily displacement** refers to the *malposition of the crown and root of a tooth in the same direction and to a similar*

extent. The terms presented above may be used to describe **tooth position** and/or **malposition** in the three planes of space:

- **Sagittal (anteroposterior) plane:** Variations in the *position* of individual teeth in the sagittal plane may be termed labial/buccal or lingual/palatal **bodily displacement**.
- **Vertical plane:** Variations in the *position* of individual teeth in the vertical plane may be termed **infraocclusion** (excessively apically positioned) and **supraeruption** or **overeruption** (excessively occlusally positioned).
- **Transverse plane:** Variations in the *position* of incisor teeth in the transverse plane may be termed mesial or distal **bodily displacement**. Variations in the *position* of individual posterior teeth in the transverse plane may be termed buccal or lingual/palatal **bodily displacement**.

Terms of bodily tooth movement in the three planes of space

The term **translation** may be defined as the *movement of a body from one point of space to another such that every point of the body moves in the same direction and over the same distance, without any form of rotation or change in size*. In dental nomenclature the term **translation** is synonymous with **bodily tooth movement**. The following terms may be used to describe **bodily tooth movement** in the three planes of space:

- **Sagittal (anteroposterior) plane:** Bodily tooth movement (translation) in the labiolingual direction for incisors and the mesiodistal direction for the buccal segments is termed **protraction** (labial incisor movement or mesial buccal segment movement) and **retraction** (lingual/palatal incisor movement or distal buccal segment movement).
- **Vertical plane:** Bodily tooth movement (translation) in the occlusal-apical direction is termed **intrusion** (apical movement) and **extrusion** (occlusal/incisal movement).
- **Transverse plane:** Bodily incisor movement (translation) in the mesiodistal direction is termed mesial or distal **bodily movement**. Bodily movement of individual posterior teeth in the buccolingual direction is termed buccal or lingual/palatal **bodily movement**.

Terms of tooth rotation around the three axes of rotation

The terminology used to describe the structural relationship of the teeth in relation to the three axes of rotation (Figure 22.2) is as follows:

- **Angulation:** This term refers to the angular deviation of the long axis of a tooth from a line perpendicular to the occlusal plane, in the *mesiodistal* direction. *Rotation of an incisor around the sagittal (labiolingual/buccolingual) axis* (also termed *second-order rotation*) leads to a change in its angulation.
- **Inclination:** This term refers to the angular deviation of the long axis of a tooth from a line perpendicular to the occlusal

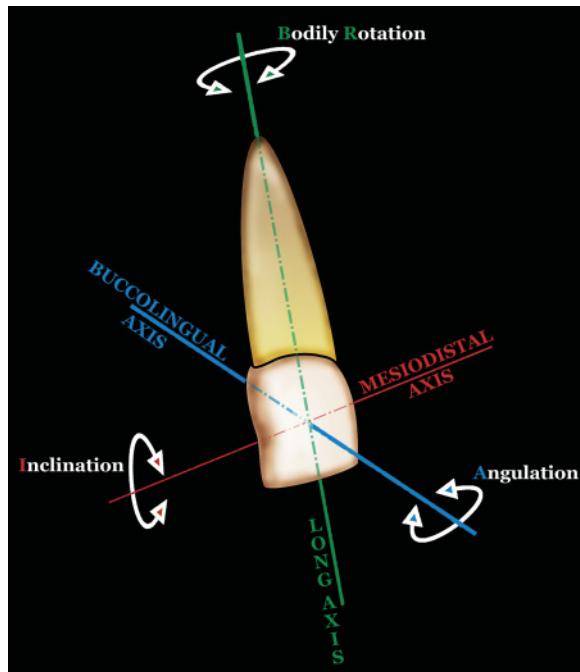


Figure 22.2 Terms of tooth rotation around the three axes of rotation.

plane, in the *labiolingual* or *buccolingual* direction. Rotation of an incisor around the *mesiodistal* (transverse/horizontal) axis (also termed *third-order rotation*) leads to a change in its inclination.

- **Proclination:** refers to anterior (labial) inclination of the crowns of the incisor teeth.
- **Retroclination:** refers to lingual/palatal inclination of the crowns of the incisor teeth.
- **Bodily rotation:** This term refers to the rotation of a tooth around its long (occlusal-apical) axis. It is also termed *first-order rotation*. Rotations are described according to the approximal surface of the tooth that is furthest from the line of the arch, e.g. a maxillary incisor may be mesio- or disto-labially rotated or mesio- or distopalatally rotated.

Note

The terms 'angulation' and 'inclination' are *not* synonymous, and should *not* be used interchangeably. Angulation refers to the *mesiodistal* and inclination refers to *labiolingual/buccolingual* position and/or movement of the teeth.

Note

The following terms are often used in orthodontics:

- **Torque:** This term refers to active orthodontic forces used to change the inclination of teeth, often by root movement.

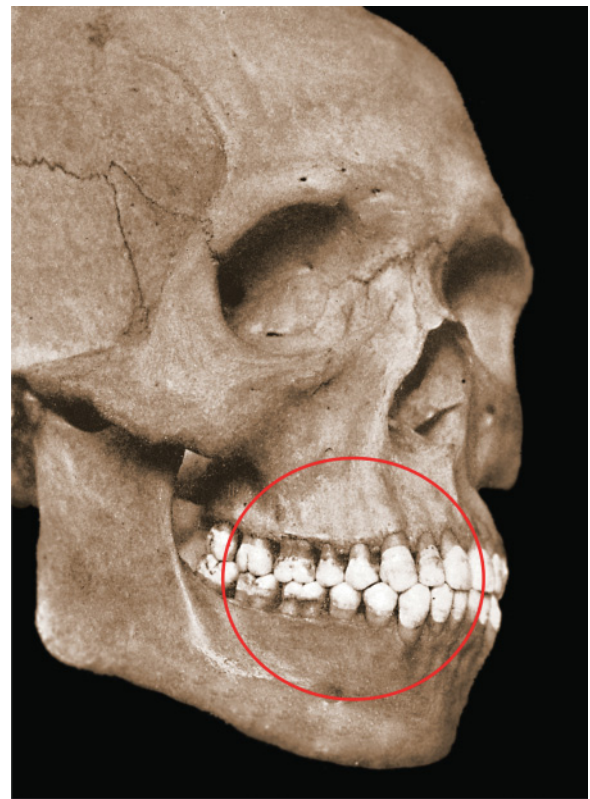


Figure 22.3 The skull named 'Old Glory' was used by Edward Angle to exemplify 'normal' dental occlusion, though it was the 'ideal' to which orthodontists were taught to strive. An element of bimaxillary dentoalveolar protrusion is evident, which does not fit the 'straight' facial profile concept, also described by Angle. (Modified from Strang.¹)

Dental occlusion

The concept of 'ideal' occlusion

The term **dental occlusion** describes the relationship of the maxillary and mandibular teeth as they are brought into functional contact. The etymology is from the Latin *occludere*, meaning 'to close up'. In laypeople's terms, the occlusion is the 'bite' of the teeth. The term '**ideal**' occlusion is a *theoretical concept* based on the morphology of unworn teeth of 'ideal' size in an 'ideal' arrangement; it is almost never found in nature (Figure 22.3).¹ The significance of the concept of 'ideal' occlusion is as the *theoretical standard* to which other occlusions may be compared.²

In contrast, the term '**normal**' occlusion has no precise definition and defies accurate description; normal occlusion is dental occlusion that allows for *minor variations* from the 'ideal', which are *functionally and aesthetically satisfactory*. More severe variations, whether in tooth position or arch relationship, are described as **malocclusion**.³ There is no precise boundary between normal occlusion and malocclusion.

- **Tip:** This term refers to active orthodontic forces used to change the angulation of teeth, often by movement of the crown.
- **Uprighting:** This somewhat vague term is sometimes employed to describe orthodontic forces used to change the angulation of a tooth by root movement.

Note

In clinical practice, evaluation of the dental arches usually begins with the **intra-arch relationships**, i.e. the tooth relationships are examined in each dental arch separately, specifically noting the *alignment* of the teeth, the sagittal and vertical position of the contact points/areas between the teeth, the presence of crowding, spacing or tooth rotations. Following this, the **inter-arch relationships**, i.e. the interdigitation of the opposing dental arches, is evaluated. Assessment of the axial angulation and axial inclination of the teeth may also be gleaned from the dental occlusion, but detailed analysis requires evaluation relative to cranio-facial reference planes.

Curves of the occlusion

Sagittal curve of occlusion

In a normal occlusion viewed from the lateral, the teeth are positioned in such a way that they follow a sagittal curve, with the mandibular cusps becoming more superiorly positioned progressively distally and the maxillary cusps following suit. In the mandibular arch this sagittal curve is termed the **curve of Spee**, after its description by the German anatomist **Ferdinand Graf von Spee** (1890).⁴ In the maxillary arch it is correctly termed the sagittal curve of occlusion, though the term 'curve of Spee' is often used to refer to both the mandibular and maxillary curves. Spee originally described the curve with its axis located in the region of the lacrimal bone, with a radius of 65–70 mm in adults.⁵ The curve was described as contacting the mandibular incisal edge, first molar mesiobuccal cusp, third molar distobuccal cusp and extending to the anterior surface of the mandibular condyle (Figure 22.4).

The sagittal curve of occlusion may be **accentuated**, e.g. if the mandibular incisors are over-erupted or the maxillary incisors are unable to fully erupt, or **reversed**, e.g. if the mandibular incisors have been unable to fully erupt as a result of a forward tongue position in a patient with a soft tissue anterior open bite, or if the maxillary incisors are overerupted. The *sagittal curve of occlusion should be described separately for the maxillary and mandibular arches*.

Note

It is important to evaluate the maxillary and mandibular sagittal curves of the occlusion separately. For example, in a severe Class II division 2 type malocclusion the maxillary and mandibular incisors tend to overerupt past each other; this creates a reverse curve in the maxillary arch and an accentuated curve of Spee in the mandibular arch (Figure 22.5). The same is true of a *skeletal* anterior open bite, in which the incisors erupt as far as they are able, but this is insufficient to establish their vertical contact. Conversely, in a patient with an anterior open bite of *soft tissue* aetiology the maxillary and mandibular incisors are prevented from erupting to their full potential by a forward resting tongue position; this leads to an accentuated curve in the maxillary arch and a reverse curve in the mandibular arch (Figure 22.6).

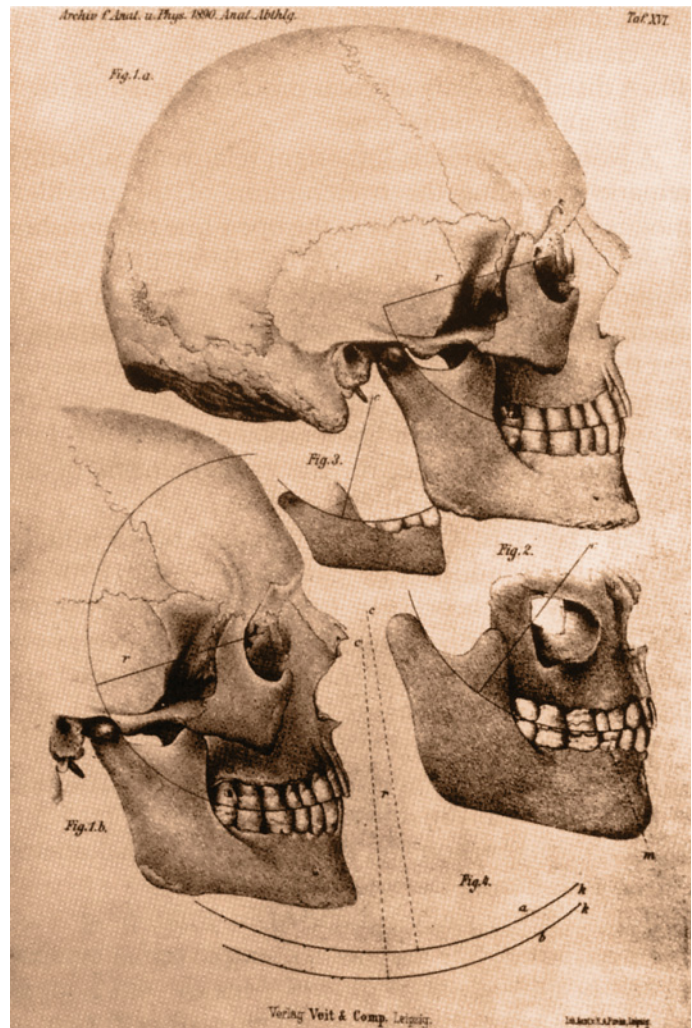


Figure 22.4 The 'curve of Spee' or sagittal curve of the occlusion. (From Spee.⁴)

Transverse curve of occlusion

In a normal occlusion viewed from the front, the mandibular posterior teeth are inclined lingually in such a way that the buccal cusps of the mandibular posterior teeth are slightly higher than the lingual cusps; this forms what is termed the **curve of Wilson**, described by the American dentist George H Wilson in 1911.⁶ It is alternatively termed the **mediolateral curve of occlusion** (Figure 22.7).

Aims of treatment and the 'six keys' to 'ideal' occlusion

It is important to have clear, objective aims before commencing treatment. The orthodontist **Lawrence F Andrews** (1972) analysed the morphological characteristics of 120 dental study models of untreated individuals with excellent dental occlusions; he studied the tooth *crowns* in this collection, in order to ascertain the characteristics found consistently in all the models.⁷ Andrews thereby described these required elements as the 'six keys to normal occlusion', although it is apparent that the

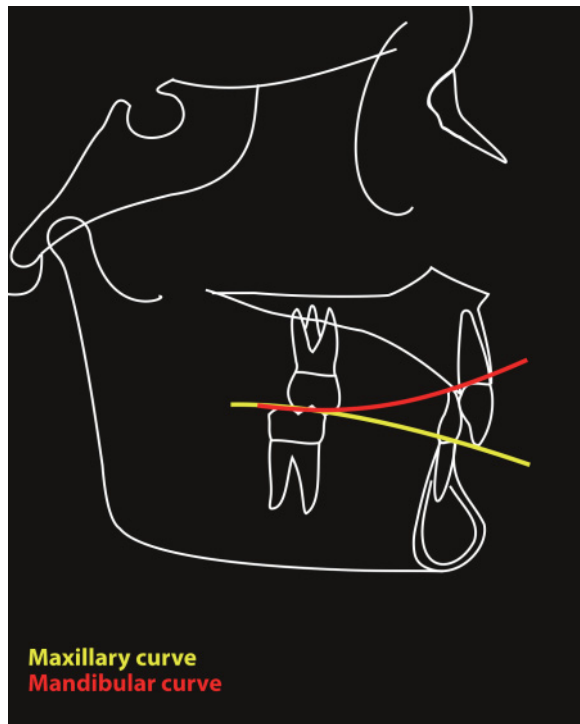


Figure 22.5 Sagittal occlusal curves: the maxillary and mandibular incisors have overerupted past each other, creating a reverse curve in the maxillary arch and an accentuated curve of Spee in the mandibular arch.

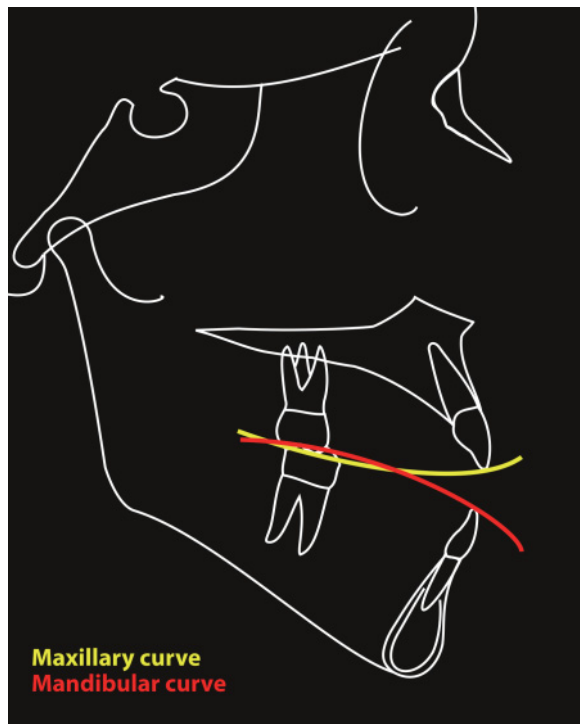


Figure 22.6 Sagittal occlusal curves: the maxillary and mandibular incisors have been prevented from erupting to their full potential by a forward resting tongue position, leading to an accentuated curve in the maxillary arch and a reverse curve in the mandibular arch.

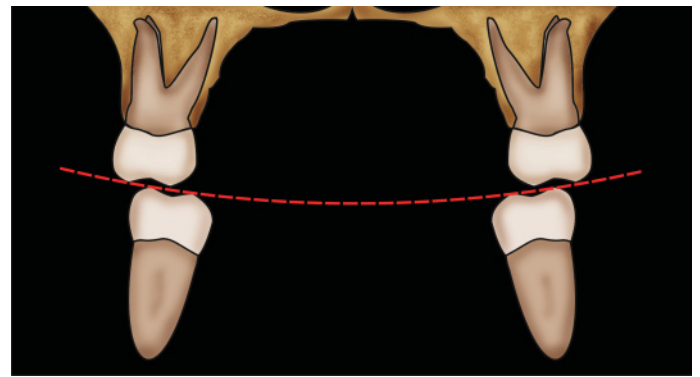


Figure 22.7 The transverse curve of occlusion is termed the 'curve of Wilson' or the mediolateral curve of occlusion.

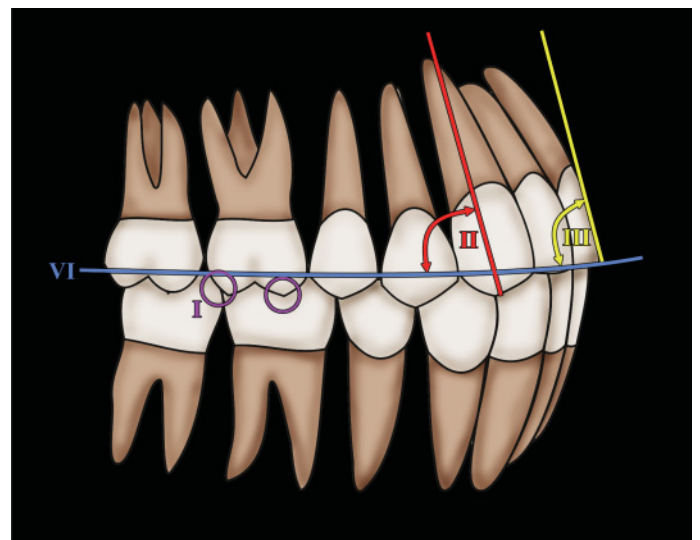


Figure 22.8 Andrews' 'six keys' to 'ideal' dental occlusion:

- Key I: molar relationship
- Key II: crown angulation (mesiodistal angulation)
- Key III: crown inclination (buccolingual)
- Key IV: no rotations (not shown)
- Key V: no interdental spaces (not shown)
- Key VI: almost flat curve of Spee.

description relates to an 'ideal' rather than a 'normal' occlusion (Figure 22.8).

- **Key I – Molar relationship:** The distal surface of the distobuccal cusp of the maxillary first permanent molar occludes (makes contact) with the mesial surface of the mesiobuccal cusp of the mandibular second permanent molar. The mesiobuccal cusp of the maxillary first permanent molar falls within the buccal groove between the mesial and middle cusps of the mandibular first permanent molar. (The canines and premolars exhibit a cusp-to-embasure relationship buccally and a cusp-to-fossa relationship lingually.)
- **Key II – Crown angulation:** This key considers the *mesiodistal angulation* of the *long axis of the clinical crown* of each tooth, rather than the long axis of the entire tooth. The gingival portion of the long axis of each crown is distal to

the occlusal (incisal) portion; the degree of mesiodistal crown angulation varies for each tooth type. (The long axis of the crown for all teeth, except molars, is judged by the mid-developmental ridge, which is the most prominent and centremost vertical portion of the labial/buccal surface of the crown. The long axis of the molar crown is identified by the dominant vertical groove on the buccal surface of the crown.)

- **Key III – Crown inclination:** Crown inclination refers to the *labiolingual* or *buccolingual* inclination of the long axis of the crown, not to the inclination of the long axis of the entire tooth. The inclination of all the crowns has a consistent scheme:
 - **Incisors:** Maxillary and mandibular incisor crowns are labially inclined to a degree sufficient to resist overeruption of their antagonists. The labial inclination permits proper distal positioning of the contact points of the maxillary teeth in relation to the respective contact points of the mandibular antagonists, allowing proper occlusion of the posterior crowns.
 - **Maxillary posterior teeth (canines to molars):** A palatal (lingual) crown inclination exists, which is relatively constant from the canines through to the second premolars and is slightly more pronounced in the molars.
 - **Mandibular posterior teeth (canines to molars):** The crowns of the mandibular posterior teeth exhibit a lingual inclination that increases progressively from the canines through to the second molars.
- **Key IV – Rotations:** No rotations are present.
- **Key V – Spaces:** There are no spaces; interdental contact points are tight.
- **Key VI – Occlusal plane:** The sagittal plane of occlusion varies from flat to a slight curve of Spee.

Correct tooth size: the ‘seventh key’ to ‘ideal’ occlusion

Bennett and McLaughlin⁸ described an additional key (**seventh key**) required for an ‘ideal’ or normal dental occlusal relationship: *correct tooth size*. The presence of a **tooth size discrepancy** between the maxillary and mandibular dental arches would otherwise result in either crowding or spacing, or compensatory angulations or inclination of the anterior teeth (Figure 22.9).

Note

It is not always possible to treat patients to such an ‘ideal’ dental occlusion. When planning the correction of occlusal anomalies a useful guideline to follow is that, in general, *maintaining or improving facial aesthetics takes precedence over attaining an ‘ideal’ dental occlusion*. For example, in a patient presenting with a severe Class II skeletal discrepancy but unwilling to undergo orthognathic surgical correction, orthodontic retraction of the maxillary incisors would be required to correct the incisor relationship; this could have disastrous consequences on the facial profile by creating a retrusive, flat upper lip and an obtuse nasolabial angle. In such a case it may be prudent to align the teeth but accept an increased incisor overjet.



Figure 22.9 Correct tooth size is the ‘seventh key’ to ‘ideal’ occlusion: in this example, the slightly small lateral incisor will need to be ‘built up’ if the other keys are to be met.

Classification of dental-occlusal relationships

Incisor relationships

Sagittal incisor relationship

The incisor classification was first described by Ballard and Wayman;⁹ it was based on Angle’s classification system, introduced by Edward Angle (1899).¹⁰ This classification now forms the widely adopted British Standards Institute’s (1983) classification of incisor relationship.¹¹ The classification is based upon the relationship between the mandibular incisor edges and the cingulum plateau of the maxillary central incisors (Figure 22.10). In patients in whom the incisor relationship is different on the two sides, the classification is determined by the general features of the malocclusion.

- **Class I:** The mandibular incisor edges occlude with or lie immediately below the cingulum plateau of the maxillary central incisors (Figure 22.11).
- **Class II:** The mandibular incisor edges lie posterior to the cingulum plateau of the maxillary central incisors. This Class has two divisions:
 - **division 1:** the overjet is increased; the maxillary central incisors are proclined or of average inclination (Figure 22.12).
 - **division 2:** the maxillary central incisors are retroclined; the overjet is usually minimal but may be increased (Figure 22.13).
- **Class III:** The mandibular incisor edges lie anterior to the cingulum plateau of the maxillary central incisors. The overjet is reduced or reversed (Figure 22.14).

Vertical incisor relationship (overbite)

The overbite is the degree of vertical overlap of the mandibular incisors by the maxillary incisors when the posterior teeth are in occlusion (Figure 22.15). Overbite depth is usually measured perpendicular to the occlusal plane, either in millimetres or as

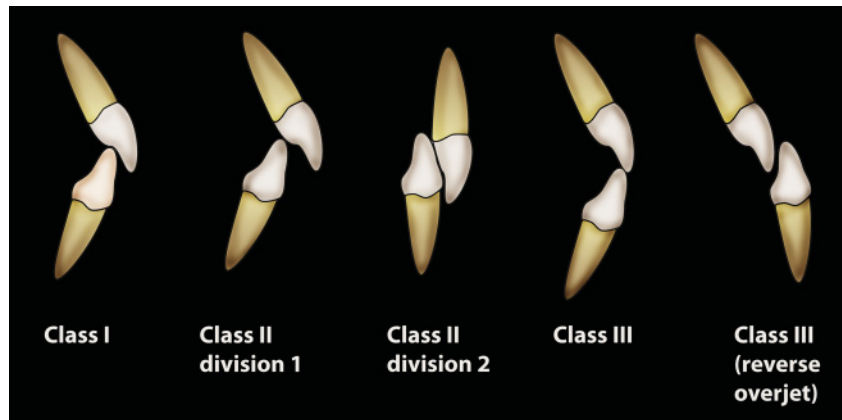


Figure 22.10 Sagittal incisor relationships.



Figure 22.11 Class I occlusion.



Figure 22.13 Class II division 2 incisor relationship.



Figure 22.12 Class II division 1 incisor relationship.



Figure 22.14 Class III incisor relationship.

the amount/percentage of the total crown height of the mandibular incisors that is overlapped by the maxillary incisors.¹² Overbite is described in terms of its *depth* (average, increased, decreased) and *incisor contact* (complete to dentition, palatal mucosa or incomplete) (Figure 22.16).

- **Average overbite:** This occurs when the maxillary incisors overlap the incisal third of the mandibular incisor crowns (2–4 mm on average).
- **Increased (deep) overbite:** Vertical overlap exceeding the incisal third of the mandibular incisors.

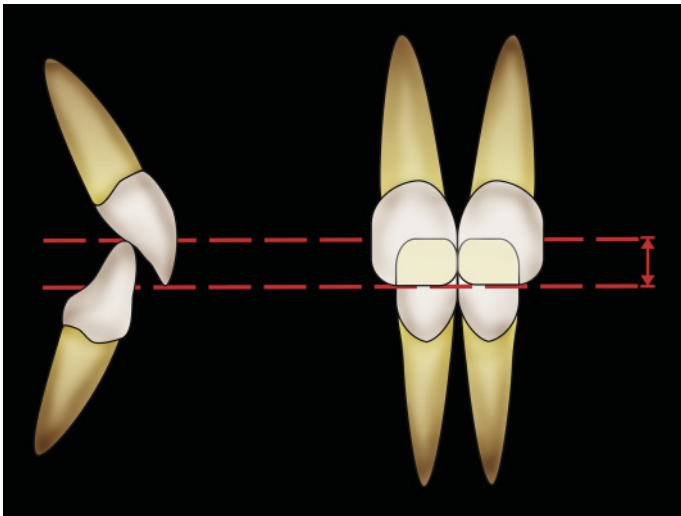


Figure 22.15 Incisor overbite.

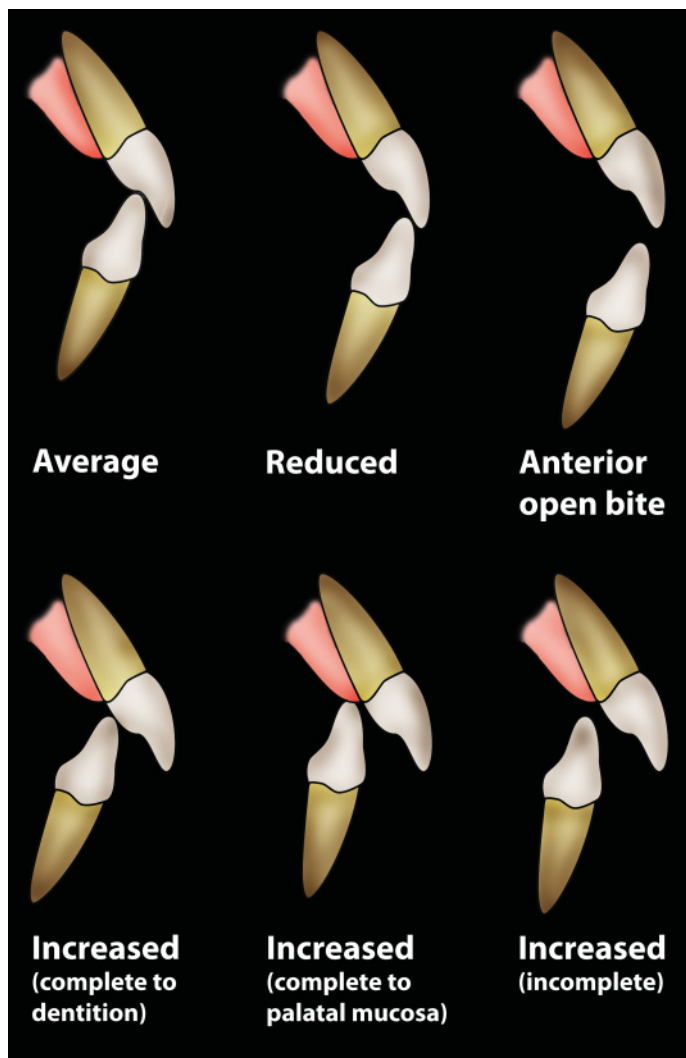


Figure 22.16 Classification of incisor overbite.

- **Decreased (reduced) overbite:** Signifies less than one-third coverage of the mandibular incisors.
- **Anterior open bite:** No vertical overlap of the incisor teeth.

Transverse incisor relationship

The term **dental midline discrepancy** describes the non-coincidence of the maxillary and mandibular dental midlines. It is important to bear in mind that the dental midlines must also be evaluated in relation to the facial midline and their respective skeletal bases.

Buccal segment relationships (canine and molar relationships)

Sagittal buccal segment relationship

- **Class I:** In a Class I molar relationship, the distobuccal cusp of the maxillary first molar occludes between the distobuccal cusp of the mandibular first molar and the mesiobuccal cusp of the mandibular second molar (Andrews' Class I) (Figure 22.17). The mesiobuccal cusp of the maxillary first permanent molar falls within the buccal groove between the mesial and middle cusps of the mandibular first permanent molar (Angle's Class I). Sagittal discrepancies may be distinguished as $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ or full unit discrepancies, with a **unit** being the mesiodistal width of one premolar. The canines and premolars exhibit a cusp-to-embrasure relationship buccally and a cusp-to-fossa relationship lingually.
- **Class II:** Mandibular molar occludes distal to maxillary molar (Figure 22.18).
- **Class III:** Mandibular molar occludes mesial to maxillary molar (Figure 22.19).

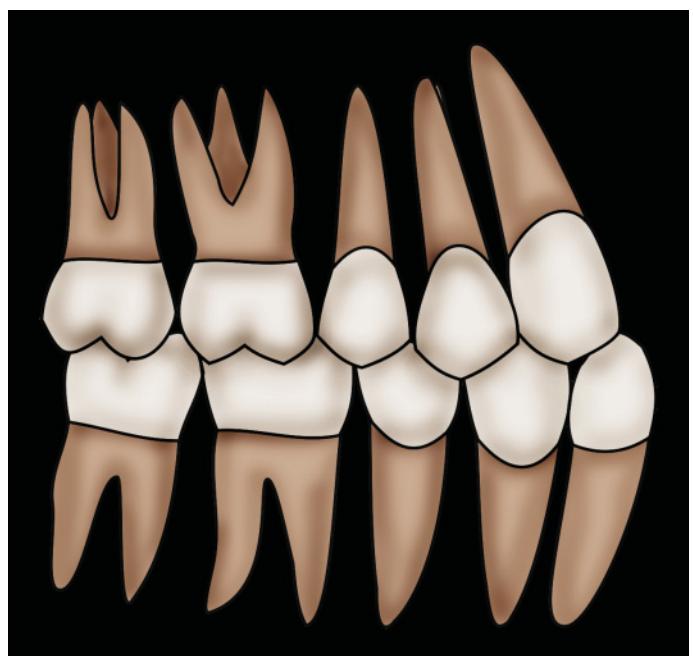


Figure 22.17 Class I buccal segment relationship.



Figure 22.18 Class II (full unit) buccal segment relationship.

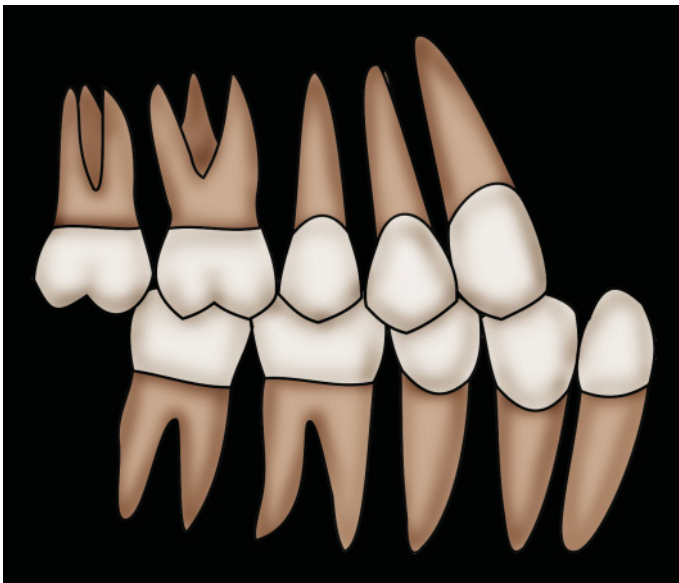


Figure 22.19 Class III (full unit) buccal segment relationship.

Vertical buccal segment relationship

- **Average buccal overbite:** Relationship of the vertical overlap of the buccal cusps of the maxillary and mandibular posterior teeth when normal cusp-to-fossa occlusion is present.
- **Lateral open bite:** A vertical space exists between the occlusal surfaces of the posterior teeth in maximum intercuspation, when eruption is complete (Figure 22.20).

Transverse buccal segment relationship (Figure 22.21)

- **Normal:** The buccal cusps of the maxillary teeth occlude buccal to those of the mandibular, with the palatal cusps of



Figure 22.20 Right-sided lateral open bite.

the maxillary molars and premolars occluding in the fossae of their mandibular antagonists.

- **Buccal crossbite:** The buccal cusps of the mandibular teeth occlude buccally to those of the maxillary teeth; may be unilateral or bilateral.
- **Lingual crossbite:** The buccal cusps of the mandibular teeth occlude lingually to the palatal cusps of the maxillary teeth; may be unilateral or bilateral.
- **Scissors bite:** Excessive lingual crossbite, when the maxillary posterior teeth occlude completely buccal to the mandibular teeth (also referred to as 'buccal non-occlusion' or 'complete lingual crossbite'); may be unilateral or bilateral.

Note

The classification of occlusal relationships and malocclusion is based on morphological characteristics, not on the underlying aetiology. In fact, a specific type of malocclusion in a given Class may result from varying aetiological factors, e.g. a Class II division 1 incisor relationship with an increased overjet may have a number of causes, such as an underlying Class II skeletal pattern with incisors of normal inclination (Figure 22.22A), or a Class I skeletal pattern with proclined maxillary incisors (Figure 22.22B). Therefore, the terms 'Class II treatment' or 'Class III treatment' are inappropriate; treatment planning cannot be based simply on the category within which a patient's occlusal characteristics fit. *The dental occlusion must always be viewed and analysed as part of the craniofacial complex, not as a solitary entity.*

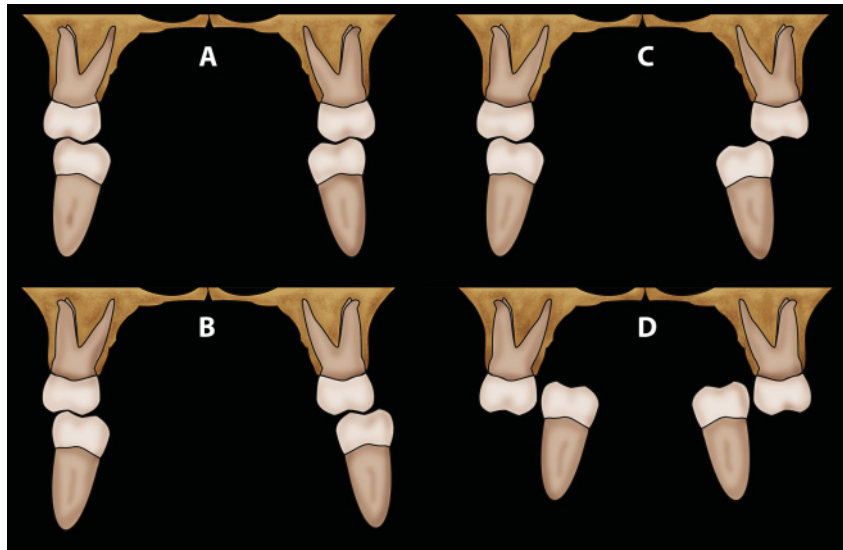


Figure 22.21 Transverse buccal segment relationship: (A) norma; (B) right-sided buccal crossbite; (C) right-sided lingual crossbite; and (D) bilateral scissors bite.

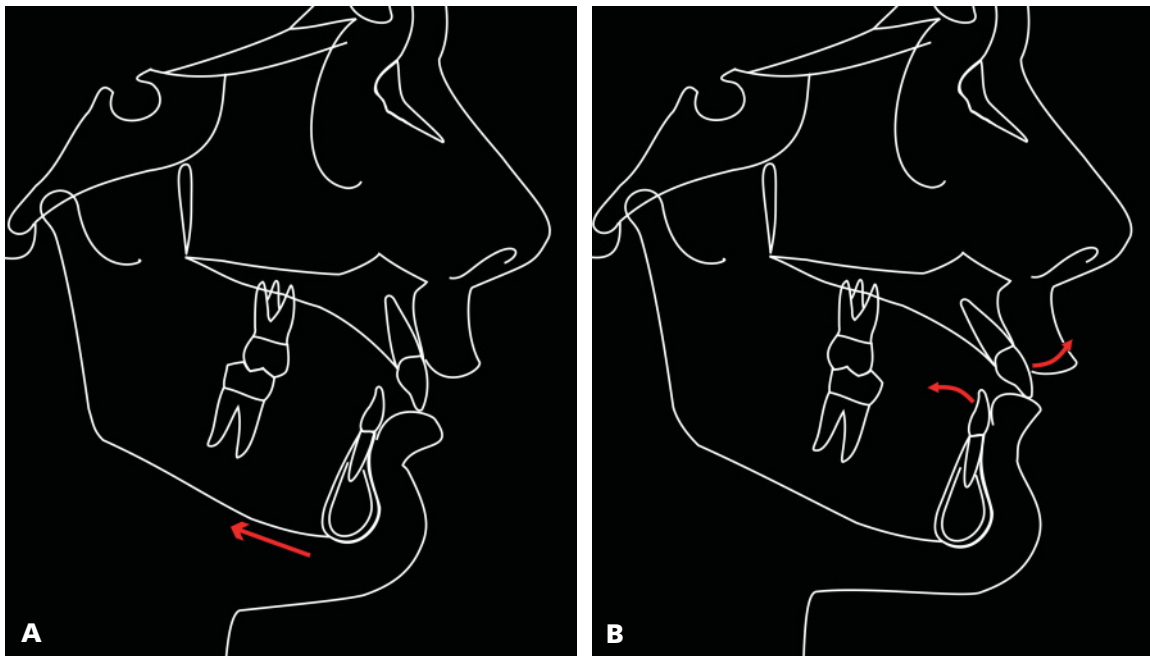


Figure 22.22 (A) Class II division 1 incisor relationship with an increased overjet due to underlying Class II skeletal pattern with incisors of normal inclination. (B) Class II division 1 incisor relationship on a Class I skeletal pattern with an increased overjet due to proclined maxillary incisors and retroclined mandibular incisors.

The term 'Class' and classification

The terms 'Class I', 'Class II' and 'Class III', originally introduced by Edward Angle to classify sagittal dental-occlusal relationships, are now widely used to describe a variety of attributes of the bimaxillary complex.^{10,13} The terms may refer to *any of the following parameters* (Figure 22.23):

- **Skeletal pattern (jaw relationship):**
 - Class I: Maxillary and mandibular skeletal bases are in a normal sagittal relationship to one another; the maxillary skeletal base is 2–3 mm anterior to the mandibular.
 - Class II: There is *relative* maxillary prominence in the sagittal plane.

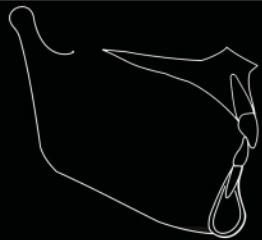
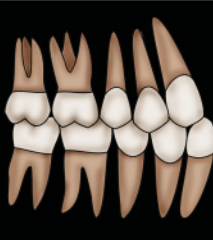
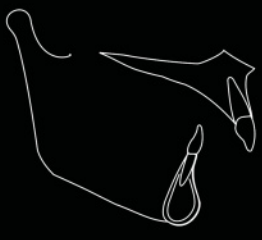
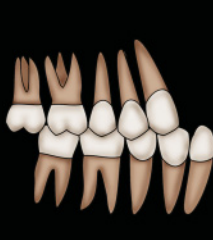
	Skeletal pattern (jaw relationship)	Incisor relationship	Buccal segment relationship	Malocclusion	Jaw growth pattern
Class I				Overall Class I-type (dental)	Forward and downward
Class II				Overall Class II-type (skeletal and/or dental)	Mandible deficient relative to maxilla (sagittal plane)
Class III				Overall Class III-type (skeletal and/or dental)	Maxilla deficient relative to mandible (sagittal plane)

Figure 22.23 The terms 'Class I', 'Class II' and 'Class III', are used to describe a variety of attributes of the bimaxillary complex: sagittal jaw relationship, incisor relationship, buccal segment relationship (canine, premolar and molar relationships), overall malocclusion type and sagittal jaw growth pattern.

- Class III: There is *relative* mandibular prominence in the sagittal plane.
- **Dental occlusion:**
 - Incisor relationship:
 - Class I
 - Class II (division 1 or division 2)
 - Class III.
 - Buccal segment relationship (canine, premolar and molar relationship):
 - Class I
 - Class II: $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ or full unit
 - Class III: $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ or full unit.
- **Malocclusion (overall):** This refers to the overall attributes of a malocclusion, e.g. a patient with a *skeletal* Class II jaw relationship due to mandibular deficiency may have a *dental* Class I incisor relationship as a result of excessively proclined mandibular incisor teeth; however, the *overall* attributes of the malocclusion may still be described as a 'Class II malocclusion'.
- **Jaw growth pattern:**
 - Class I: The bimaxillary complex grows forward and down in a normal relationship.

Note

During average, normal jaw growth, pogonion will move 2mm down for every 1mm of forward growth (Figure 22.24).¹⁴

- Class II: Mandibular growth relative to the maxilla is deficient in the sagittal plane.
- Class III: Mandibular growth relative to the maxilla is excessive in the sagittal plane.

It is important to bear in mind that these *various classifications are largely independent*. The terms 'Class I', 'Class II' or 'Class III' must be used in context. For example, a patient with a Class I incisor relationship may have a Class II skeletal pattern and Class III molar relationship.

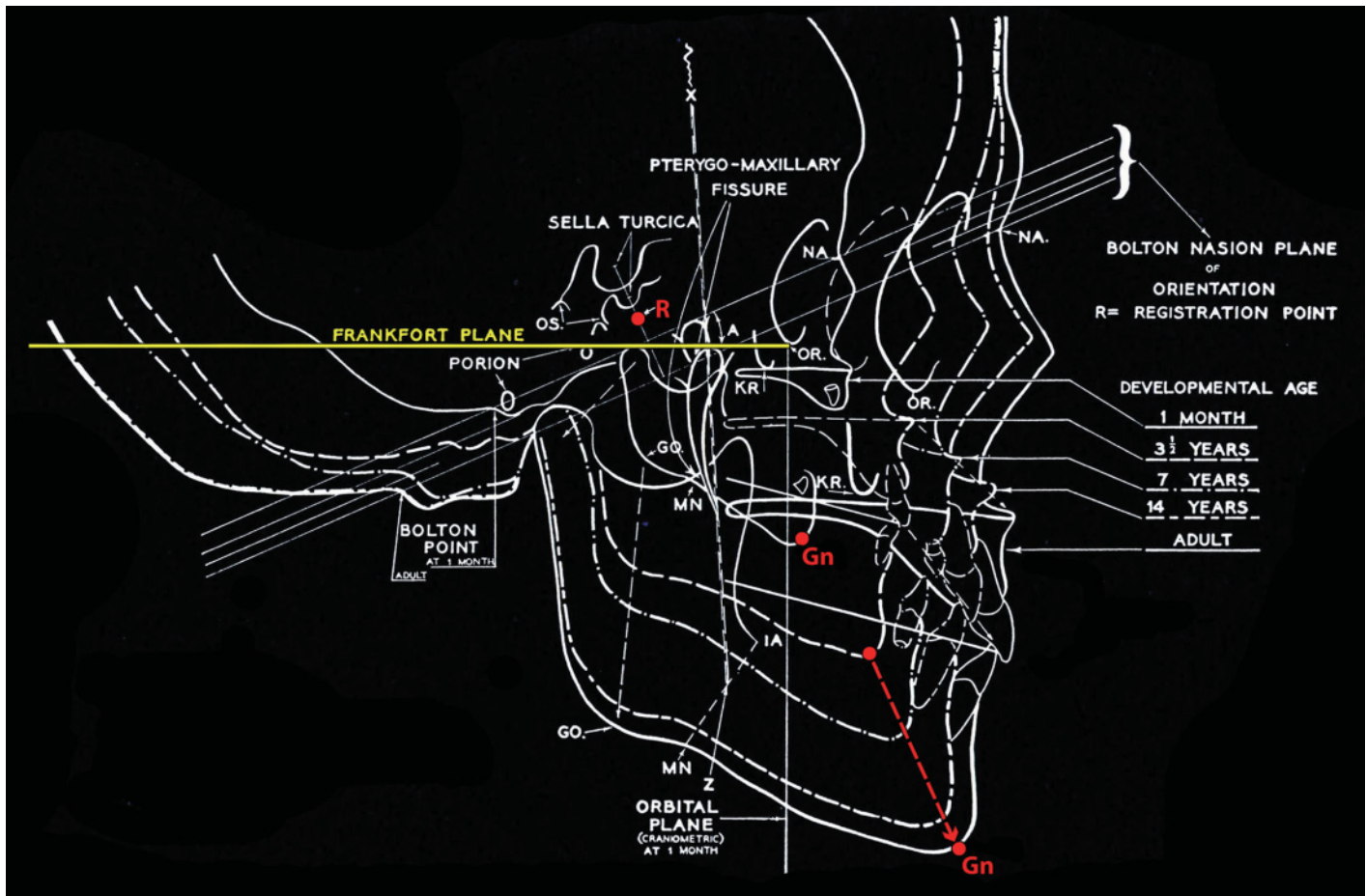


Figure 22.24 'Normal' or average growth of the face from Broadbent's serial growth study, superimposing serial lateral cephalometric radiographs from the Bolton study records. Broadbent superimposed the radiographs on what he termed R-point (registration point) such that the Bolton planes were parallel. The forward and downward growth of the jaws is evident. (Modified with permission from Broadbent,¹⁴ © The EH Angle Education and Research Foundation.)

The aetiology of malocclusion

The aetiology of a malocclusion is the study of its causative factor(s). A thorough understanding of the aetiological factors resulting in an individual's malocclusion is important in clinical diagnosis and in the **prevention** and **stable correction** of dental-occlusal and dentoskeletal discrepancies.

The aetiology of a malocclusion may be:

- **Genetic (hereditary):** Malocclusion and dentofacial disproportions with a predominantly **genetic determination** are very difficult, if not impossible, to correct with attempts to modify the environment, e.g. the genetic determination of severe mandibular excess is very strong, hence attempts to modify growth tend to be unsuccessful. The patient is better treated with orthognathic surgery once growth has ceased.
- **Environmental:** If a predominantly environmental aetiological factor is determined, its influence may be prevented, e.g. the influence of a digit sucking habit prevented early may be negligible.

- **Multifactorial:** The aetiology of most malocclusions is part genetic and part environmental.

In clinical practice it is useful to classify the aetiology of malocclusion under the following categories: skeletal factors, soft tissue factors, local factors and habits.

Skeletal factors

The sagittal, vertical and transverse jaw relationship has a considerable influence on the dental occlusal relationship as a result of **dentoalveolar compensation**. Dentoalveolar compensation describes the *variations in the positions of the teeth that may compensate for variations in the skeletal pattern*, i.e. it is nature's way of trying to get the teeth to meet when the jaws are growing away from one another. In the normal situation, the erupting maxillary and mandibular teeth are guided towards each other by the surrounding **soft tissue envelope** of the tongue, lips and cheeks; hence, they erupt into a position of **soft tissue equilibrium** between the opposing forces of the tongue and lips/cheeks

(Figure 22.25). Therefore, in the presence of *sagittal* or *transverse* skeletal discrepancies, alterations in the inclination of the teeth *compensate* for the skeletal discrepancy (Figure 22.26). In such cases, the occlusal discrepancy will appear less severe than the underlying skeletal discrepancy. For example, in a patient with a severe Class III skeletal pattern, the dentoalveolar compensation involves proclination of the maxillary incisors and retroclination of the mandibular incisors. This compensatory mechanism may be unsuccessful either because the skeletal discrepancy is too severe or because the soft tissue pattern is unfavourable. For example, in a Class II skeletal discrepancy, if the soft tissue are unfavourable and the lower lip is unable to control the labial aspect of the maxillary incisors and instead falls behind them it

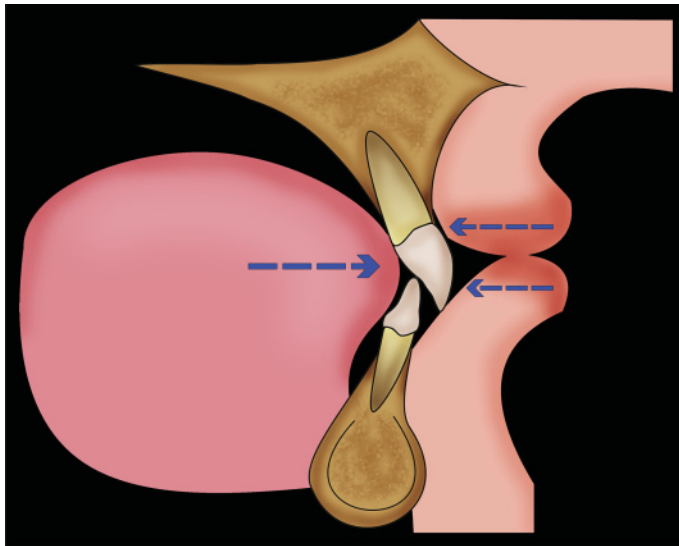


Figure 22.25 The soft tissue envelope of the tongue, lips/cheeks; the teeth are in a position of soft tissue equilibrium between the opposing forces of the tongue and lips/cheeks.

will lead to their proclination and thereby magnify rather than compensate for the skeletal discrepancy.

In the *vertical* plane, the incisors will tend to overerupt to compensate for increasing lower anterior face height, unless a forward tongue position prevents their overeruption. If the face height is dramatically increased, the incisors may not be able to fully compensate and an anterior open bite will ensue. However, there will be an increased curve of Spee in the mandibular arch and a reverse curve in the maxillary arch; this is termed a skeletal open bite, i.e. the aetiology of the anterior open bite is predominantly skeletal (Figure 22.27A). The presence of a soft tissue (i.e. excessively forward tongue position) aetiology results in a reverse curve of Spee in the mandibular arch and an accentuated curve in the maxillary arch, termed a soft tissue anterior open bite (Figure 22.27B).

Orthodontic preparation for orthognathic surgery requires **orthodontic decompensation** of the dental arches in *all three planes of space*, i.e. the process of removing the dentoalveolar compensations that may be present in the sagittal, transverse and vertical planes. The correct position of the teeth within their own skeletal base is established, thereby permitting adequate surgical correction of skeletal discrepancies.

Soft tissue factors

The orofacial musculature surrounds the teeth and jaws, with the teeth in a position of **soft tissue equilibrium** between the forces from the lips/cheeks on the outside and the tongue on the inside. Variations in this **soft tissue envelope** thereby influence tooth position. Such variations may involve the *direction*, *magnitude* and *duration* of the muscular forces on the teeth. The soft tissue factors involved include:

- **Lips:** Lip lines, activity, morphology and posture (see Chapter 17) (Figure 22.28).
- **Tongue:** The size, position and activity of the tongue may influence dental development and tooth position. A **forward tongue position** or large tongue (**macroglossia**) may impede

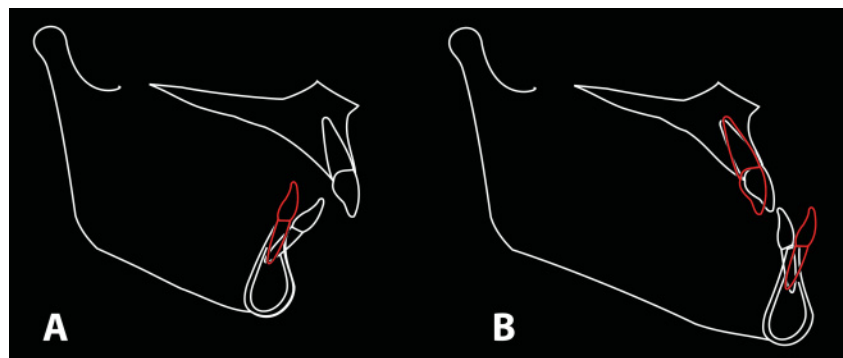


Figure 22.26 Dentoalveolar compensation. (A) Proclination of the mandibular incisors often occurs to compensate for a Class II skeletal relationship; decompensation in preparation for mandibular advancement surgery would require their retroclination to a correct inclination for the mandibular skeletal base. (B) Proclination of the maxillary incisors and retroclination of the mandibular incisors may occur to compensate for a Class III skeletal relationship.

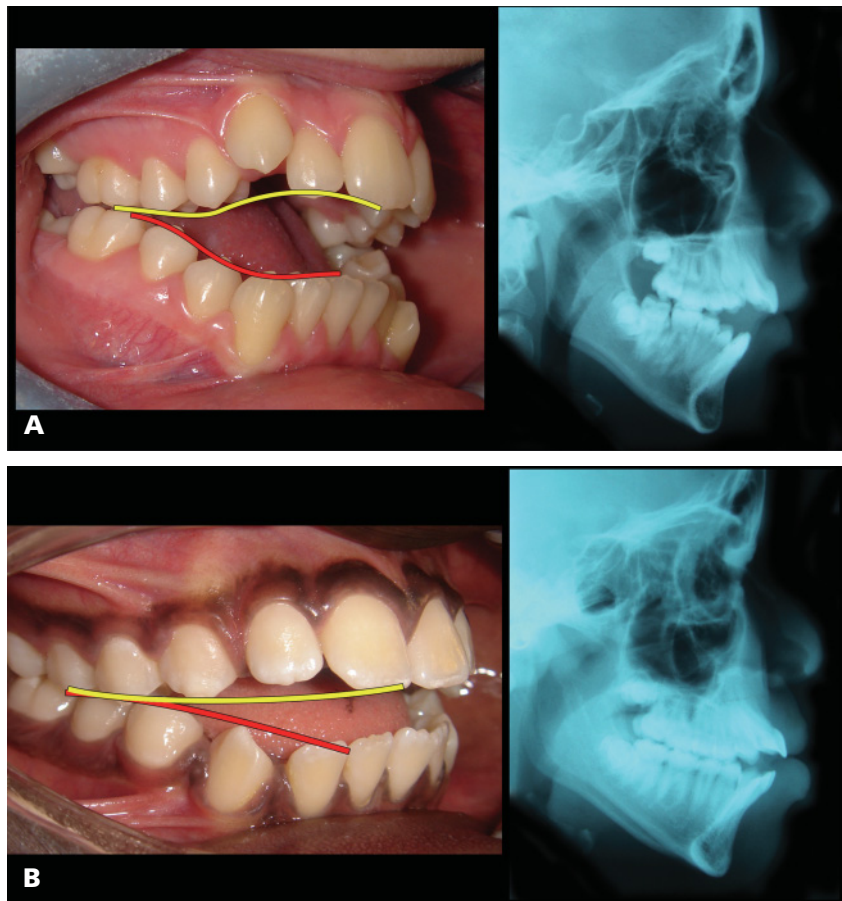


Figure 22.27 Combined aetiology anterior open bite: (A) predominantly skeletal; and (B) predominantly soft tissue.



Figure 22.28 The maxillary left central incisor has been 'trapped' anterior to the lower lip and has proclined, whereas the maxillary right central incisor has remained behind the lower lip.

incisor eruption, resulting in an anterior open bite of soft tissue aetiology. A rare neuromuscular condition termed an **endogenous tongue thrust** may result in an overactive tongue being forcibly thrust forward during swallowing; the pathognomonic features are:

- Soft tissue anterior open bite
- Symmetrical bimaxillary dentoalveolar proclination
- Lisp.
- **Adenoids:** There is some evidence that enlarged adenoids may result in increased resistance to nasal airflow and mouth breathing; the head is tilted backwards to reduce airway obstruction, resulting in downward muscular pull on the anterior mandible from the stretched muscles and fascia between the anterior mandible, hyoid bone and shoulder. The typical 'long face' pattern may be termed **adenoid facies**, which may be accompanied by an anterior open bite.
- **General neuromuscular pathology:** Patients with conditions affecting muscular tone and contraction, such as **muscular dystrophy**, may be prone to increased lower anterior face height and large anterior open bites (Figure 22.29).¹⁵

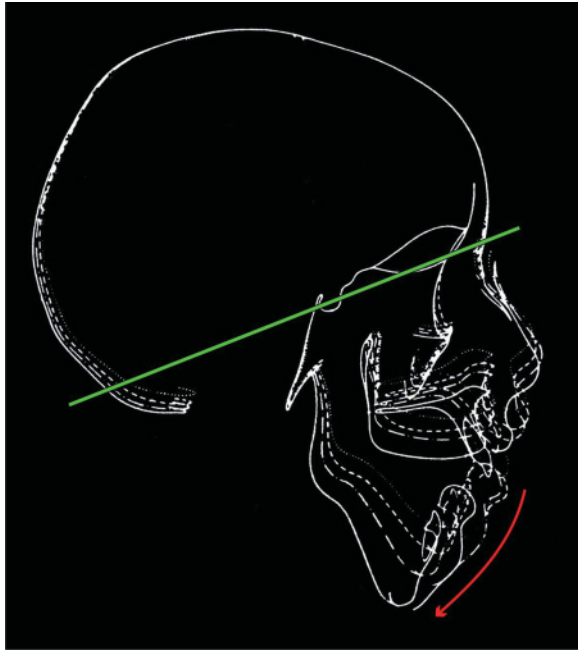


Figure 22.29 Excessive vertical facial growth pattern and posterior mandibular rotation in a patient with muscular dystrophy; cephalometric radiographs superimposed from ages 4 $\frac{3}{4}$ years, 6 $\frac{3}{4}$ years, 8 $\frac{3}{4}$ years and 12 $\frac{1}{2}$ years. (Modified from Kreiborg et al.¹⁵ with permission from Elsevier.)

Local factors

Dentoalveolar or other local factors are those that have a more **localized effect** on tooth position or dental occlusion. Local factors may result in the following:

- **Variations in tooth number:**
 - **Hypodontia:** Developmental absence of one or more deciduous or secondary teeth.
 - **Supernumerary teeth:** Teeth in excess of the normal series, which commonly affect the anterior maxilla.
 - **Early loss of teeth:** Early loss of deciduous teeth, often due to extraction as a result of dental caries, may lead to loss of space for developing or erupting permanent teeth. Permanent teeth may be lost due to traumatic avulsion, particularly the maxillary incisor teeth.
- **Variations in tooth size:**
 - **Dentoalveolar disproportion:** This is the term given to a relative mismatch in size between the teeth and jaws, resulting in either dental arch crowding or spacing.
 - **Macrodonia:** Teeth that are too large; may be localized or generalized.
 - **Microdonia:** Teeth that are too small; may be localized or generalized.
- **Variations in tooth position:**
 - **Infraocclusion:** This may occur as a consequence of failure of eruption of a tooth due to **ankylosis** (the anatomical fusion of root cementum and alveolar bone), or



Figure 22.30 Characteristic asymmetrical anterior open bite resulting from a prolonged digit sucking habit.

as **primary failure of eruption** (a poorly understood condition, probably genetic, affecting the first and second permanent molars).

- **Impaction:** Teeth may be impacted or ectopic.
- **Transposition:** The position of teeth may be interchanged, e.g. maxillary canines and first premolars.
- **Frenal attachments:** A low, fleshy upper labial frenal attachment may be associated with a maxillary midline diastema.

Habits

A prolonged digit sucking habit is one that continues past the age of 6–7 years when the permanent incisors erupt. The *duration* and *intensity* are important; greater than six hours per day results in significant occlusal disturbance, commonly resulting in an asymmetrical anterior open bite, proclined maxillary incisors, retroclined mandibular incisors and transverse narrowing of the maxillary arch (Figure 22.30).

Oral health

Evaluation of oral health is an integral part of the clinical assessment of the craniofacial complex. Pathology may affect the soft and/or hard tissues of the oral cavity.

Dental condition

Undiagnosed **dental caries** will lead to pulpal and eventually periapical pathology; a thorough clinical examination of the dried teeth in good light is required, together with examination of good quality bitewing radiographs to look for interproximal carious lesions.

Tooth surface loss (**tooth wear**) is becoming a common problem. Wear may result from **attrition** (due to repetitive occlusal contact between the teeth), which occurs to a certain

degree with age but may become excessive in the presence of parafunctional activities such as bruxism; **abrasion** (due to excessive mechanical wear by a foreign abrasive material, e.g. poor tooth brushing technique) or **erosion**, which may result from excessive and frequent intake of dietary acids or gastric reflux. The diagnosis of *anorexia* or *bulimia nervosa* often follows the initial recognition of the dental erosive pattern pathognomonic of acid regurgitation.

Oral hygiene and gingival/periodontal condition

The standard of oral hygiene is often a good indicator of a potential patient's motivation and cooperation with proposed treatment. Poor **oral hygiene** and subgingival plaque deposits will lead to gingival inflammation (**gingivitis**) and eventually **periodontal disease**, with consequent alveolar bone loss and increased mobility of the teeth. A history of gingival bleeding on tooth brushing is indicative of gingivitis; the gingivae will appear oedematous and red and will bleed on gentle subgingival probing. The presence of thin attached gingivae or signs of **gingival recession** must be noted, as these may become worse with orthodontic or dental restorative treatment. The presence of a **lower labial frenum** may also lead to eventual recession of the gingivae labial to the mandibular central incisor teeth.

Oral mucosa

Clinical inspection of the intraoral soft tissues includes the palate, buccal mucosa, tongue and floor of the mouth.

Occlusal function

Examination of the static dental occlusion is followed by evaluation of dynamic occlusal and temporomandibular joint function.

Dynamic occlusal function

Incisal guidance: This is evaluated by asking the patient to protrude the mandible while keeping the teeth together. The mandibular incisal edges slide down the palatal surface of the maxillary incisors and there is simultaneous disclusion of the posterior teeth. During this movement, the mandibular condyles will slide down the anterior slope of the glenoid fossae.

Lateral occlusal guidance: This is evaluated by asking the patient to move the mandible laterally while keeping the teeth together. The side to which the mandible moves during a lateral excursion is termed the **working side**; the opposite side is the **non-working side**. If there is complete disclusion of the buccal segments as the mandibular canine slides down the palatal surface of the maxillary canine, this is referred to as **canine guidance**. If the majority of the buccal teeth remain in contact, this is referred to as **group function**. Either way, on lateral excursion of the mandible contact of the teeth on the non-working side is undesirable, and termed **non-working side interferences**.

Note

The static tooth relationship into which patients habitually close their teeth is termed **centric occlusion (CO)**, or **intercuspal position (ICP)**. **Centric relation (CR)**, alternatively termed the **retruded contact position (RCP)**, is a reproducible *jaw position, independent of tooth contact*, which conceptually is the position of the mandible relative to the skull when the masticatory muscles are at their most relaxed and least strained position. The articular disc must be in position and the mandibular condyles in their most superior, retruded unstrained position in the glenoid fossae. *When the teeth occlude in maximum intercuspation, the mandible ideally should be in a position of centric relation.*

Temporomandibular joint function

The temporomandibular joint (TMJ) is a synovial joint formed by the articulation of the mandibular condyle with the glenoid fossa of the temporal bone bilaterally. The bony surfaces are separated by an articular disc (meniscus) and surrounded by a fibrous capsule. The following must be evaluated.

Range and path of mouth opening: The pathway of mouth opening may be evaluated by observing the patient in frontal view. The mandible should open smoothly without significant **lateral deviation**. The lower limit of the range of normal (unstrained) range of mouth opening is approximately 35 mm in women and 40 mm in men; less than this is considered reduced mouth opening. The lower limit of normal excursive movements is approximately 8 mm, best evaluated by measuring the deviation of the dental midlines on excursion.

Pain: There should be no pain or discomfort on mouth opening or closing, or on manual palpation of the muscles of mastication.

Joint noises: Joint noises may be listened for with a stethoscope, though loud clicks are often easily audible. **Clicking** of the temporomandibular joints on mouth opening and/or closing is often related to excessive laxity of the meniscal ligaments. **Crepitus** or 'grating' sounds may be suggestive of joint inflammation or degenerative joint changes.

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Chapter 23 Smile Aesthetics

Introduction

The analysis of the smile is an important part of facial aesthetic evaluation.

Importance of the smile in facial aesthetics

‘Those cherries fairly do enclose
Of orient pearl a double row,
Which when her lovely laughter shows,
They look like rose-buds fill’d with snow.’

Thomas Campion (1567–1620), English poet and physician, *Cherry-Ripe*¹

When looking at or communicating with an individual, the observer’s eyes flit between the individual’s eyes and mouth, which are the most expressive regions of the face. In fact, in considering features that are most influential to pleasing facial aesthetics, the appearance of the smile has been ranked second only to the eyes.²

Note

Most of the described guidelines in orthodontics and prosthodontics relating to smile and dentogingival aesthetics are derived from the literature on denture prosthetics.

Types of smile

‘There is a smile of love,
And there is a smile of deceit,
And there is a smile of smiles
In which these two smiles meet.’

William Blake (1757–1827), *The Smile* (c. 1805)³

Two types of smile have been described in the scientific literature (Figure 23.1):

- **Posed smile:** This is a *voluntary* smile, not linked with emotion, e.g. asking an individual to smile when taking a photograph. It is fairly reproducible. It may also be termed a **non-Duchenne smile**, a ‘simulated’ smile or even a ‘false’ smile. The term **social smile** was used by the English poet Thomas Gray (1716–71).⁴
- **Spontaneous smile:** This is an *involuntary* smile, often linked with joyous emotion. It involves larger facial movements, including squinting of the eyes (hence the term ‘smiling with the eyes’), flaring of the nostrils and maximum elevation of the lips. It may also be termed a **Duchenne smile**, or a ‘true’ smile.

Note

The main distinction between the posed and spontaneous smile is the involvement of the **orbicularis oculi**, or ‘eye’ muscle, in the latter. In *The Mechanism of Human Facial Expression* (1862)⁵ the pioneering French neurophysiologist **Guillaume-Benjamin-Amand Duchenne de Boulogne** (1806–75) proposed that this involvement would distinguish the smile of enjoyment from a simulated smile. For example, 5-month-old infants show the ‘eye-muscle’ smile when the mother approaches, but a smile without the eye muscle when approached by a stranger. Moreover, when a spontaneous smile is shown in adults, the pattern of brain activity found with genuine enjoyment occurs, but that brain activity pattern is not found when the posed smile alone is shown. To pay tribute to Duchenne for this discovery, **Paul Ekman** (1990) proposed the spontaneous smile, which involves the action of both the zygomaticus major and the orbicularis oculi muscles, be termed the ‘Duchenne smile’ (see Figure 3.11).⁶

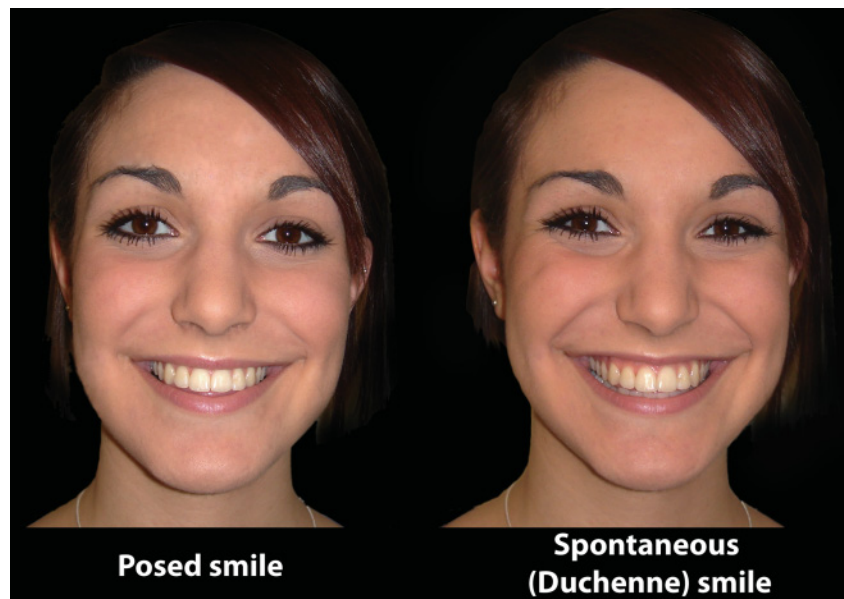


Figure 23.1 Smile types.

The renowned English naturalist **Charles Darwin** (1809–82), in *The Expression of the Emotions in Man and Animals* (1872),⁷ correctly emphasized that the clue to recognizing the true smile of enjoyment (the spontaneous or Duchenne smile) is the lowering of the lateral portion of the eyebrow. This is a subtle change, but together with lowering of the superior palpebral fold, it is a reliable sign that the outer fibres of orbicularis oculi have been contracted, and enjoyment is occurring. Ekman⁸ has demonstrated that crow's feet wrinkles, and the bagging of the skin below the eye, can be produced by a strong action of the zygomaticus major muscle alone, without any contraction of the orbicularis oculi.

The generation of a smile

Two stages of smile formation have been described:⁹

- **Stage I:** The levator muscles contract, thereby elevating the upper lip until resistance is met from the cheek fat present in the nasolabial folds.
- **Stage II:** This involves further elevation of the upper lip against the resistance of the nasolabial folds and also elevation of the nasolabial folds themselves. Various muscle groups are involved in this movement (see Figure 3.5), including the levator labii superioris muscles, the zygomaticus major and the superior fibres of the buccinator muscle. The orbicularis oculi muscles may also participate in the effort to elevate the upper lip against the nasolabial fold, which produces the characteristic squinting of the eyes that accompanies a spontaneous smile.

Note

Darwin⁷ made an interesting observation, noting that 'when a man closely shuts one eye he cannot avoid retracting the upper lip on the same side.' Ekman⁸ has pointed out that the elevation of the outer corner of the upper lip that occurs when the ipsilateral eye is firmly closed is due to the action of the orbicularis oculi alone, which *stretches the skin* and causes this change in the upper lip, and not the activation of another muscle in the midface.

Stage I is similar to the posed, non-Duchenne smile; stage II is the spontaneous, Duchenne smile.

Clinical evaluation

Lip aesthetics

Aesthetic evaluation of the lips is an important part of the diagnostic process and is the starting point for the clinical evaluation of the smile. The acronym 'LAMPP' may be used to assess the lines, activity (function), morphology (height and form), posture and prominence of the lips. The aesthetic evaluation of the lips is described in detail in Chapter 17.

Lip lines

The **lip lines** represent the vertical position of the upper and lower lips in relation to the anterior dentition. The 'ideal' dentolabial relationship results when the upper lip covers approximately the upper two-thirds of the maxillary incisor crowns at rest, with 2–4 mm maxillary incisor exposure; women tend to have significantly greater maxillary incisor exposure than men (Table 23.1).¹⁰ The interlabial separation is no more than 2–3 mm.

Table 23.1 Incisor exposure at rest relative to sex

Sex	Maxillary central incisor exposure (mm)	Mandibular central incisor exposure (mm)
Male	1.91	1.23
Female	3.40	0.49

Data from Vig and Brundo.¹⁰

The upper and lower lips are brought into contact with little or no circumoral contraction, with the lower lip covering the incisal third of the maxillary central incisors.

The upper and lower lip lines must be evaluated with the patient in repose (resting lip lines) and in the dynamic state of speech and smiling.

- The **resting upper lip line** may be defined as the vertical relationship between the inferior border of the upper lip and the incisal edge of the maxillary incisor teeth. The 'ideal' resting upper lip line is with the upper lip covering the upper two-thirds of the maxillary incisor crowns at rest, with 2–4 mm maxillary incisor exposure.
- A **high resting upper lip line** (sometimes termed a 'high lip line') leads to exposure of the entire clinical crown and associated gingivae of the maxillary incisor teeth, leading to excessive incisor exposure and sometimes an associated 'gummy' appearance *at rest* (see Figure 17.6).
- A **low resting upper lip line** (sometimes termed a 'low lip line') leads to exposure of less than 2 mm of the maxillary incisor crowns. The maxillary incisor display may be non-existent at rest and in extreme cases, in speech and in smiling (the 'no tooth' smile) (see Figure 17.7).

Note

There is a gradual reduction in maxillary incisor exposure in repose with advancing age. This is often accompanied by an increase in mandibular incisor exposure, both in repose and in animation (speech or smiling).

Vig and Brundo¹⁰ have provided normative mean values for incisor exposure in repose for Caucasian adults related to age (Table 23.2 and Figure 23.2):

- The **resting lower lip line** may be defined as the vertical relationship between the superior border of the lower lip and the incisal edge of the maxillary incisor teeth. The lower lip should cover the incisal third of the maxillary central incisors.

In the animated state of smiling, the upper lip line should elevate to such a degree that the inferior upper lip border reaches the maxillary incisor gingival margin, displaying the entire incisor crowns, interdental papillae and up to 1–2 mm of gingivae.

Note

Anecdotally, gingival exposure of up to 1–2 mm in smiling is more attractive in women than men.

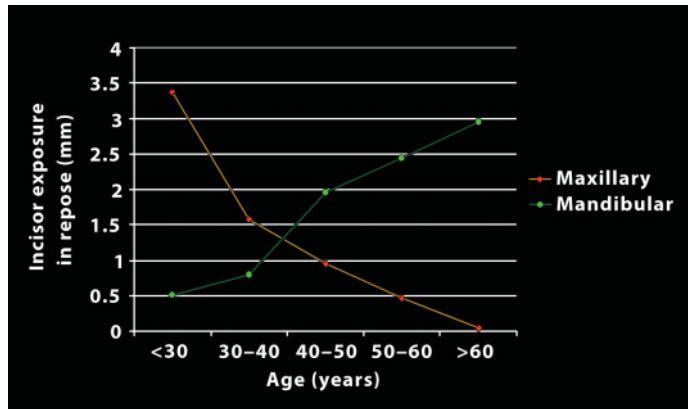


Figure 23.2 Line diagram illustrating changes in incisor exposure in relation to age – mandibular incisor exposure increases and maxillary incisor exposure decreases with age (see Table 23.2).

Table 23.2 Incisor exposure at rest relative to age

Age (years)	Maxillary central incisor exposure (mm)	Mandibular central incisor exposure (mm)
Up to 29	3.4	0.5
30–39	1.6	1.0
40–49	1.0	2.0
50–59	0.5	2.4
60+	0	3.0

Modified from Vig and Brundo.¹⁰

The *resting* and *dynamic* lip lines are also correlated with the **type of malocclusion**, with which a patient may present. For example, mandibular incisor exposure may be increased in Class III malocclusion (Figure 23.3A). Conversely, maxillary incisor exposure is often increased in Class II malocclusion, particularly if the maxillary incisors are excessively proclined (Figure 23.3B).

Upper lip–maxillary incisor relationship

Leonardo da Vinci described the importance of the 'strongly movable section of the face around the mouth and chin in determining facial expression', emphasizing the importance of observing the face in animation as well as in the static state.¹¹ One of the most important facial aesthetic parameters is the



Figure 23.3 (A) Increased mandibular incisor exposure in Class III malocclusion. (B) Increased maxillary incisor exposure in Class II malocclusion with proclined maxillary incisors.

degree of exposure of the maxillary incisor teeth in relation to the upper lip, both at rest and in animation, i.e. in speech and in smiling.¹²

The vertical exposure of the maxillary incisors in relation to the upper lip at rest should be 2–4 mm, and on smiling the entire

crown of the maxillary incisors should be exposed, with up to 1–2 mm of associated gingiva. A spontaneous smile, which is involuntary and expresses joyous emotion, tends to raise the upper lip slightly more than a posed smile, which is voluntary (Figure 23.4).

The ‘lip–incisor relationship’ depends on a number of factors (Figure 23.5), including:¹²

- 1. **Upper lip height:** Increased upper lip height will tend to reduce maxillary incisor exposure, and vice versa. Upper lip height, measured from subnasale (Sn) to stomion superius (Sts), is approximately 22 ± 2 mm in adult males and 20 ± 2 mm in adult females. Mid-philtral height is roughly equal to, or 1–2 mm less than, commissure height (measured from the oral commissure to a horizontal line through subnasale) (see Figure 17.21). Reduced mid-philtral height results in an unattractive inverted arc appearance of the upper lip (see Figure 17.22); surgical procedures to increase the upper lip height may be required in such cases.

Note

It is important to take into consideration the *increase in upper lip height* that occurs in adolescent patients with continued growth, particularly when treatment planning individuals with a short upper lip relative to commissure height. The upper lip height increases by approximately 3 mm between the ages of 10 and 20 years in male and female individuals (Table 23.3).¹³ Intrusion of maxillary incisors in the adolescent patient may lead to inadequate incisor display in later years.

Table 23.3 Increase in upper lip height with age

Age (years)	Upper lip height (mm) (SD $\pm$ 2)	
	Male	Female
10	19	18
20	22	21

Modified from Bhatia and Leighton.¹³



Figure 23.4 Upper lip–maxillary incisor relationship. (A) The vertical exposure of the maxillary incisors in relation to the upper lip is approximately 2–4 mm in repose. (B) With a posed smile the entire crown of the maxillary incisors should be exposed, with up to 1–2 mm of associated gingiva. (C) A spontaneous smile tends to elevate the upper lip slightly more than a posed smile.

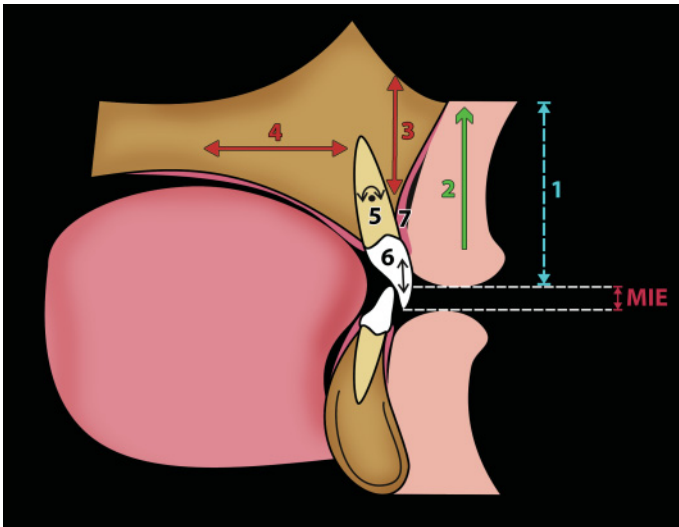


Figure 23.5 The 'lip-incisor relationship' and maxillary incisor exposure (MIE) depends on the following factors:

1. Upper lip height
 2. Smile curtain – the muscular capacity to elevate the upper lip
 3. Vertical position of the anterior maxilla and incisor teeth
 4. Sagittal position of the anterior maxilla and incisor teeth
 5. Inclination of the maxillary incisor teeth
 6. Maxillary incisor crown height
 7. Vertical level of the labial maxillary incisor gingival margins
2. **Smile curtain:** The 'smile curtain' may be defined as the muscular capacity to elevate the upper lip. The elevation of the upper lip from repose to full smile exhibits considerable individual variability, averaging 7–8 mm (range 2–12 mm).¹⁴ If the position of the maxilla and maxillary incisors in relation to the face is correct, yet the patient presents with a 'gummy smile' due to vertical hypermobility of the upper lip, the option of botulinum toxin type A injections to the levator muscles of the upper lip is available. Alternatively, surgery to reduce the mobilization and elevation of the upper lip may be undertaken using the technique originally described by Kostianovsky and Rubinstein,¹⁵ later re-described by Kamer¹⁶ (Figure 23.6).
3. **Vertical position of the anterior maxilla and incisor teeth:** The more inferior the position of the anterior maxilla, the greater the exposure of the maxillary incisors, and vice versa.

Note

Vertical maxillary excess (VME) may result from excessive inferior development of the maxilla (Figure 23.7).¹² This is often accompanied by excessive gingival display at rest and on smiling, sometimes referred to as a 'gummy smile'. Treatment, therefore, centres on superior repositioning of the maxilla. In certain cases **anterior VME** may be due to excessively overerupted maxillary incisors (for example, Class II division 2 malocclusion), in which case the treatment of choice will either be an anterior segmental impaction of the maxilla, or orthodontic intrusion of the maxillary incisors and associated gingivae (Figure 23.8).

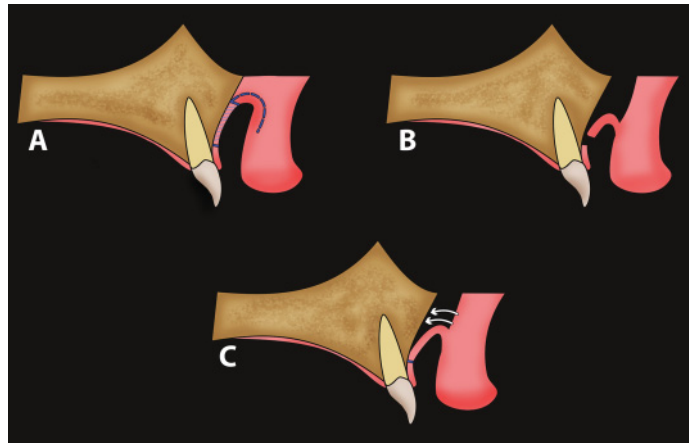


Figure 23.6 Kostianovsky and Rubinstein's method of reducing upper lip mobilization when hypermobility of the upper lip is the primary aetiology of a 'gummy smile'.¹⁵ A horizontal strip of mucosa is excised from the labial surface of the alveolar mucosa, extending from the anterior alveolus region to the second molar region bilaterally. The upper border of the strip is the reflection of the upper labial sulcus and the lower border parallels it approximately 3 mm above the gingival margin. (A) The strip of mucosa is removed, leaving the periosteum intact. (B) A wide flap from the vestibular aspect of the upper lip is turned downward and sutured to the labial alveolar mucosa. (C) The surface between the alveolar periosteum and upper lip musculature is sealed; the resultant synechia reduces the elevation of the upper lip in animation.



Figure 23.7 Vertical maxillary excess (VME) – this case demonstrates total VME, with excessive exposure of the anterior and posterior maxillary dentition and associated gingivae, i.e. the 'gummy smile' extends posteriorly.

4. **Sagittal position of the anterior maxilla and incisor teeth:** The more anterior the position of the maxillary incisors, the greater the exposure of the maxillary incisors, and vice versa.

Note

The increase in incisor exposure that occurs with maxillary advancement (or reduction in incisor exposure with maxillary setback) surgery must be taken into consideration; concomitant maxillary impaction or inferior repositioning may be required in order to obtain an adequate upper lip-incisor relationship.

Figure 23.8 Anterior vertical maxillary excess (anterior VME) – this is due to excessive eruption of the maxillary incisor teeth and associated anterior gingivae, i.e. the ‘gummy smile’ is only evident anteriorly.



5. **Inclination of the maxillary incisor teeth:** Retroclination of proclined maxillary incisors towards the correct inclination increases the incisor exposure, as the teeth rotate around their centre of resistance (Figure 23.9). Maxillary incisor crown inclination may be ideally evaluated on a profile smiling view.
6. **Maxillary incisor crown height, including the presence of incisal wear:** Short maxillary incisor crowns and vertical wear of the incisor crowns reduces incisor exposure. Average maxillary central incisor crown height is approximately 10 mm.
7. **Vertical level of the gingival margins on the labial surface of the maxillary incisor crowns:** It is important to note that the gingival margins of the maxillary incisors may migrate gingivally until late adolescence (described as **delayed apical migration** of the gingival margin), reducing gingival exposure and exposing the normal crown height. In adolescent patients with excessive gingival exposure, the gingival sulcular depth may be assessed with a periodontal probe. Normal midfacial sulcular depth is about 1 mm, with the cementoenamel junction located at the depth of the sulcus. If the sulcular depth is found to be significantly greater than 1 mm in the absence of gingival inflammation, it may take a number of years for the gingival margin to migrate to the normal relationship, i.e. the diagnosis is delayed apical migration (Figure 23.10). In such cases, gingivectomy may be required.¹⁷ Gingivectomy or crown lengthening procedures may also be required in adults with short clinical crowns and excessive gingival display.

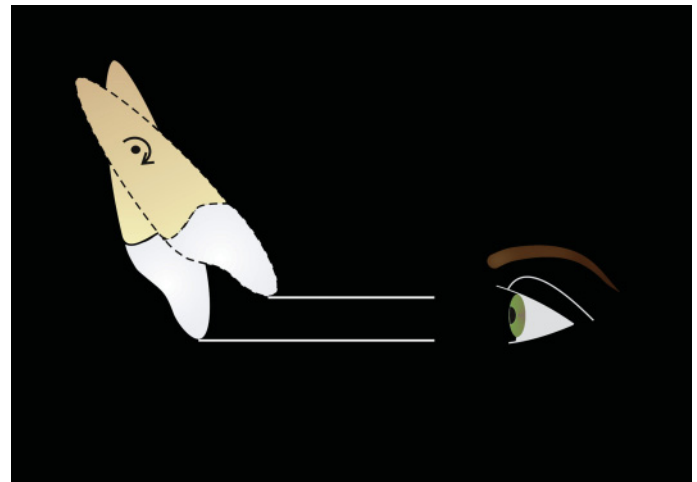


Figure 23.9 Retroclination of proclined maxillary incisors towards the correct inclination increases the incisor exposure, as the teeth rotate around their centre of resistance.

Incisor exposure and phonetic analysis

The position of the maxillary central incisors in relation to the upper lip is the key to smile aesthetics. All other teeth are positioned relative to the maxillary central incisors. **Phonetic analysis** may be employed to help determine the position and degree of exposure of the maxillary incisors in relation to the lips.¹⁹

‘F’ and ‘V’ sounds: These sounds are produced when the incisal edges of the maxillary incisors and canines make *light, momentary contact* at the wet-dry line of the lower lip. Phonetic analysis permits evaluation of the ideal vertical level of the maxillary incisor edges; i.e. maxillary incisor edges should not be positioned or restored more inferiorly than this parameter.

‘E’ sound: Prolonged pronunciation of the ‘E’ sound creates an interlabial gap, which is occupied to a variable extent by the maxillary incisor teeth. In younger patients the interlabial gap should be occupied almost entirely by the maxillary incisor teeth, whereas in elderly individuals this gap will be partially occupied by the maxillary incisors. This parameter is helpful in determining the vertical level of the maxillary incisal edges.

Note

Treatment planning for the correction of a **deep incisor overbite** (excessive vertical overlap of the maxillary and mandibular incisor teeth) requires accurate preoperative diagnosis. If the lower anterior facial height (LAFH) is correct, the aetiology of the deep overbite will be dentoalveolar. In such cases, extrusion of the molar teeth to reduce the overbite is best avoided, as this would increase the LAFH. Intrusion of the maxillary incisor teeth must be undertaken *sparingly*, and bearing in mind that in adolescent patients the upper lip height will increase with growth, overall leading to reduced maxillary incisor exposure and an ‘aged’ appearance to the smile. Therefore, in a large number of patients it is preferable to *actively intrude the mandibular rather than the maxillary incisors*. As always, accurate diagnosis is essential for correct treatment planning.¹⁸

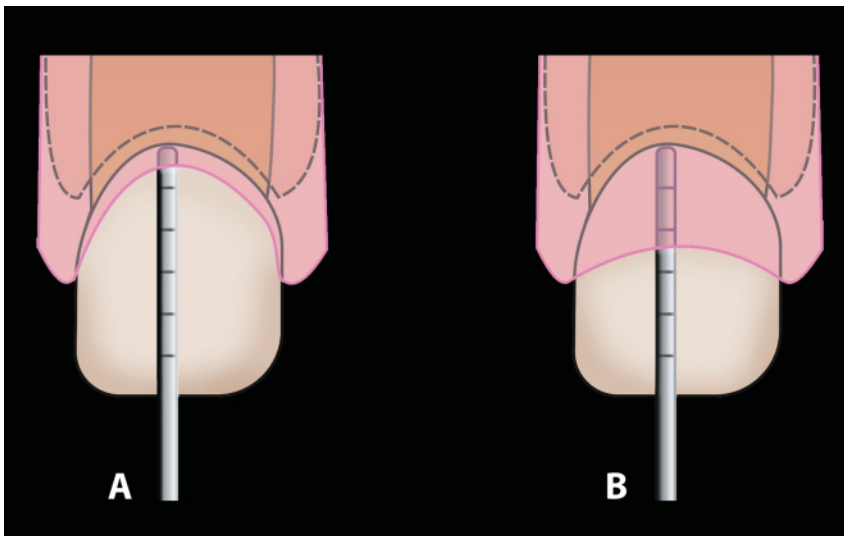


Figure 23.10 Gingival sulcus depth may be measured by probing the sulcus with a periodontal probe on the labial aspect of the tooth. **(A)** Normal gingival sulcus depth is about 1 mm, with the cemento-enamel junction located at the depth of the sulcus. **(B)** Sulcus depth significantly greater than 1 mm, in the absence of gingival inflammation, results from delayed apical migration; determination of the anatomical crown height specifies the amount of gingiva that may be removed.

‘M’ sound: The prolonged ‘M’ sound helps to place the patient in the mandibular rest position, with an interocclusal **freeway space** of 1–3 mm. It also helps to place the labial musculature in repose. This helps the prosthodontist determine the occlusal vertical dimension, which will be between 1 mm and 3 mm less than this rest position, and permits the orthodontist and surgeon to evaluate maxillary incisor exposure in relation to the upper lip with the soft tissues in repose.

‘S’ sound: Creation of the ‘S’ sound, described as the ‘S’ position, requires a space of 1–1.5 mm between the maxillary and mandibular incisor teeth, permitting air to be forced between the mandibular incisal edges and the palatal surfaces of the maxillary incisor teeth. Alternatively, some patients protrude the mandible into an edge-to-edge incisor relationship, albeit with the same space; i.e. *the teeth do not make contact during enunciation of the ‘S’ sound.*²⁰ The ‘S’ position may be used to determine the anterior occlusal vertical dimension (OVD), which will be approximately 1.5 mm closed from the ‘S’ position to achieve occlusal contact. The correct position and thickness of the palatal surface of the maxillary incisors and labial surface of the mandibular incisors may also be determined by the ‘S’ sound.²¹

Note

Phonetic analysis and ageing: The maxillary incisors exhibit greater exposure on smiling, whereas the *mandibular incisors tend to exhibit greater display during normal speech*. Patients usually examine their ‘smile’ in a mirror, and are often unaware of the degree of mandibular incisor exposure in normal speech; it is not uncommon for patients to claim that they ‘only want straight top teeth, as the lower teeth do not really show!’. The *degree of mandibular incisor exposure during normal speech becomes even more pronounced with advancing age*, as a result of sagging of the circumoral soft tissues (Figure 23.11). It is important for clinicians to educate their patients regarding this phenomenon during the treatment planning phase.



Figure 23.11 The degree of mandibular incisor exposure during normal speech becomes even more pronounced with advancing age, as a result of sagging of the circumoral soft tissues.

Note

It is important to always use and compare the results of phonetic analysis with the results of comprehensive dentofacial and smile analysis. Only methodical and thorough clinical evaluation will permit correct diagnosis.

Incisor exposure and anterior occlusal guidance

When planning to restore the height of the maxillary incisors, three parameters must be evaluated:

- **Aesthetics:** The aesthetic parameter is the exposure of the maxillary incisors in relation to the upper lip with the patient in repose. (See above section 'Upper lip–maxillary incisor relationship'.)
- **Anterior occlusal guidance:** Anterior occlusal guidance, also termed **incisal guidance**, may be examined by asking the patient to protrude the mandible while observing the dental occlusion. The incisal edges of the mandibular incisors slide down the palatal surface of the maxillary incisors, simultaneously resulting in disclusion (separation) of the posterior dentition. Maxillary incisor restorations may fail as a result of unwanted **protrusive occlusal interferences** if the incisor guidance is sacrificed at the expense of aesthetics.
- **Phonetics:** Phonetic analysis will permit restorations of such height that phonetics are not compromised.²² (See above section 'Incisor exposure and phonetic analysis'.)

Smile symmetry

In this context, smile symmetry refers to the bilateral symmetry of the **smile frame** during animation, i.e. the relative vertical position of the oral commissures in smiling.²³ There may be a difference in the extent of elevation of the left and right halves of the upper lip and oral commissures in smiling (Figure 23.12).



Figure 23.12 Asymmetrical smile: There is a difference in the extent of elevation of the left and right halves of the upper lip and oral commissures in smiling and perhaps in the extent of lower lip depression. This must not be misdiagnosed as a transverse cant of the maxillary occlusal plane.

A minor difference is acceptable and may even be deemed attractive; Elvis Presley's famous smile is the classic example. However, excessive differential elevation of the left and right sides of the upper lip may result from reduced unilateral muscular tone.

Note

An asymmetrical smile, and/or obliquity of the intercommissural plane, may lead to the misdiagnosis of a transverse cant of the maxillary occlusal plane.

Dynamic upper lip curvature

The upper lip curvature refers to the curvature of the upper lip formed in the animated state of smiling as observed in the frontal view; it is evaluated as the curvature from the middle of the vermilion of the upper lip to the lateral commissures. It is mainly directed by an individual's muscular anatomy involved in the development of a smile, but also may depend on the dentoskeletal morphology, e.g. if severe bimaxillary dentoalveolar protrusion is corrected, it is likely that the upper lip curvature on smiling may alter.

The upper lip curvature is described as **straight** when the lateral commissures and the central vermilion of the upper lip are at the same vertical level *on smiling*; **upward** if the commissures are higher than the central vermilion and **downward** when the commissures are lower than the central vermilion (Figure 23.13). Straight and upward lip curvatures are deemed more attractive. In a normal Caucasian population, the prevalence of straight (45%) and downward (43%) upper lip curvatures was found to be approximately equal, whereas upward (12%) lip curvature was less common.²⁴

Orientation of the transverse occlusal plane

The presence of a transverse cant of the maxillary occlusal plane is an important factor in the evaluation of anterior smile aesthetics. A *true* transverse cant may be of skeletal (true maxillary skeletal asymmetry) or dentoalveolar (differential unilateral dental eruption) aetiology (see Figure 16.21). The clinical result is *rotation of the maxillary occlusal plane around the sagittal axis*. It is important to bear in mind that an *apparent* transverse cant may result from soft tissue smile asymmetry, i.e. there is no transverse cant, but the asymmetrical smile gives the visual impression of a maxillary cant (see above section on 'Smile symmetry').



Figure 23.13 Dynamic upper lip curvature: (A) straight; (B) upward; (C) slightly downward; and (D) downward.

Note

It is absolutely vital to distinguish between *true* and *apparent* transverse maxillary occlusal canting. Misdiagnosis of an apparent cant as a true cant will lead to incorrect treatment, e.g. unilateral maxillary impaction, leading to the iatrogenic creation of a true cant. Diagnosis is only possible with *accurate clinical evaluation*. The transverse maxillary incisal plane, maxillary canine plane (between the canine tips), and the premolar and molar planes may be evaluated separately using a wooden tongue spatula or a dental mirror handle in frontal view. The orientation of these planes may be compared with the true horizontal plane (with the patient in natural head position) or the interpupillary plane in the absence of vertical orbital dystopia.

Orientation of the sagittal occlusal plane

The presence of an unnatural sagittal cant of the maxillary occlusal plane may have detrimental consequences on smile aesthetics. Poor aesthetics may result if the posterior plane of occlusion is established too high, e.g. from excessive posterior impaction of the maxilla, or too low, e.g. from posterior vertical maxillary excess (posterior VME) due to excessive downward vertical growth of the posterior maxillary dentoalveolus. In patients with posterior VME the posterior teeth may be observed to 'hang down' below the plane of the maxillary incisors on smiling, which is detrimental to smile aesthetics (Figure 23.14).

For ideal aesthetics the **sagittal maxillary occlusal plane**, from the anterior maxillary incisal edge to the posterior molar cusp tips, should be *approximately parallel* to **Camper's plane** (also termed the **alar-tragal** or **naso-tragal line**), which runs from the middle of the tragus of the ear to the nasal alar base. Camper's plane, commonly used in the construction of complete prosthetic dentures, is said to make an angle of approximately 8° with the Frankfort Horizontal (or true horizontal) plane (Figure 23.15). Intraorally, the sagittal maxillary occlusal plane should extend posteriorly to a point midway up the mandibular retro-molar pad.

Smile curvature (smile arc)

The **smile curvature**, alternatively termed the **smile arc** or **smile line**, may be defined as the relationship of the curvature of the incisal edges of the maxillary anterior dentition (**incisal edge curvature**) to the curvature of the upper border contour of the lower lip (**lower lip curvature**) in a posed smile. The **incisal edge curvature** is a hypothetical curve drawn along the incisal edges of the maxillary anterior teeth. The importance of this concept was proposed by John Frush and Ronald Fisher (1958) in the dental prosthetic literature.²⁵

In an 'ideal' smile, the incisal edge curvature runs *parallel* to the lower lip curvature (Figure 23.16). The incisal edges should be just at the border of the lower lip, though there may be a slight separation; the appearance is acceptable if the lower lip just, but not excessively, covers the incisal edges.²⁶ If the incisal edge curvature is **flat** or **reverse** relative to the lower lip curvature, or if the lower lip contour is abnormal, the smile may be unattractive (Figure 23.17).²⁷



Figure 23.14 In patients with posterior vertical maxillary excess the posterior teeth may be observed to 'hang down' below the plane of the maxillary incisors, which may be evident on smiling. In this patient there is a 'gummy smile' anteriorly, but the gingival exposure is even greater posteriorly.

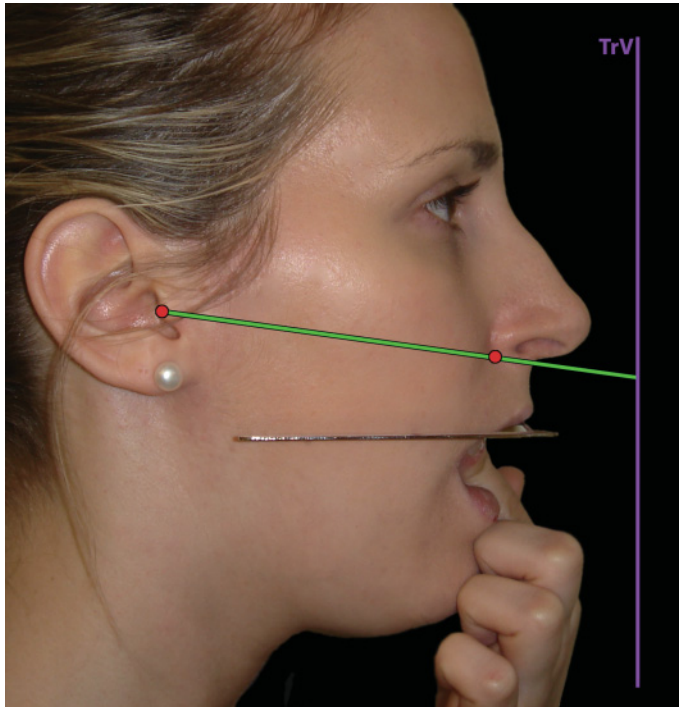


Figure 23.15 Patient with posterior vertical maxillary excess, demonstrating the inclination of the maxillary occlusal plane with a Fox's occlusal guide plane. The maxillary occlusal plane should 'ideally' be parallel to the alar-tragal line (Camper's plane, assuming a normally positioned ear), making an angle of approximately 8° with the true horizontal plane, equivalent to a posterior-inferior angle of 98° to the true vertical plane (TrV).



Figure 23.16 'Ideal' smile curvature (smile arc).



Figure 23.17 (A) Flat smile curvature. (B) Reverse smile curvature.

Note

Burstone²⁸ has made an important and valid observation regarding the 'smile arc'. The smile curvature is to a great extent determined by the inclination of the maxillary occlusal plane in the sagittal plane, e.g. if the maxillary occlusal plane is inclined upwards anteriorly, the incisal edges will move away from the lower lip, flattening the smile curvature. Differential posterior impaction of the maxilla will result in the maxillary occlusal plane being inclined downwards anteriorly, increasing the smile curvature. Therefore, the smile curvature depends on the inclination of the occlusal plane, which may be demonstrated with a simple experiment, i.e. tilting the head upwards will result in an *apparent* flattening of the smile curvature, whereas tilting the head downwards results in an *apparent* increase in the smile curvature (Figure 23.19).

Additionally, extrusion of the maxillary central incisors relative to the lateral incisors, even up to 0.5 mm, in order to improve the 'smile arc' may be deemed unattractive by patients. These parameters must be well understood prior to utilising a 'vague soft tissue reference line like the lower lip in smiling' in treatment planning.²⁸

Note

Inadvertent, iatrogenic flattening or reversal of the incisal edge curvature may occur in orthodontic treatment as a result of poorly controlled, excessive or unnecessary intrusion of the maxillary incisors or incorrect vertical positioning of incisor brackets. Unintentional *intrusion of the maxillary incisors relative to the canines* will flatten or reverse the incisal edge curvature, potentially creating an unattractive smile curvature (Figure 23.18).

Dental midlines

The relationship of the dental midlines to their *respective jaws* and to the **facial midline** must be evaluated.¹²

- **Maxillary dental midline:** This may be assessed in relation to the midpoint of the upper lip (Cupid's bow). In addition to the relationship of the maxillary incisors to the facial midline, their **transverse angulation** must also be assessed, as increased transverse crown angulation in frontal view is detrimental to dentofacial aesthetics (Figure 23.20).

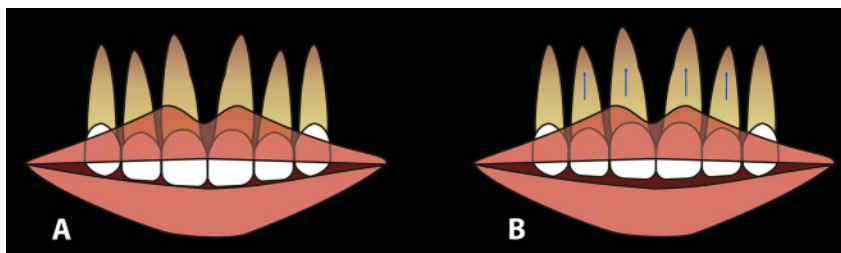


Figure 23.18 (A) 'Ideal' smile curvature. (B) Inadvertent, iatrogenic flattening of the incisal edge curvature may occur in orthodontic treatment as a result of poorly controlled, excessive or unnecessary intrusion of the maxillary incisors relative to the canines.



Figure 23.19 Burststone²⁸ has described a simple experiment to demonstrate that the smile curvature is influenced by the inclination of the maxillary occlusal plane. **(A)** Tilting the head downwards (represents the maxillary occlusal plane inclined downwards anteriorly) results in an *apparent* increase in the smile curvature. **(B)** Normal smile curvature in natural head position (represents normal inclination of the maxillary occlusal plane). **(C)** Tilting the head upwards (represents the maxillary occlusal plane inclined upwards anteriorly) results in an *apparent* flattening of the smile curvature.

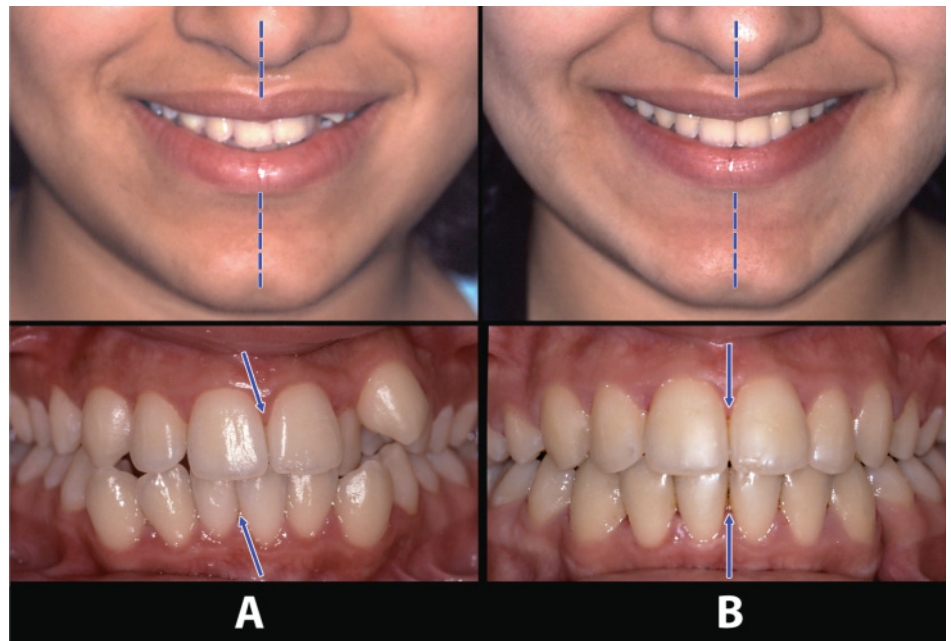


Figure 23.20 **(A)** Maxillary dental midline to the left and mandibular dental midline to the right of the facial midline; the degree of midline shift is exaggerated by the incorrect incisor angulations. **(B)** Orthodontic treatment has corrected the incisor angulations and the maxillary and mandibular dental midlines are coincident with the facial midline.

- **Mandibular dental midline:** This is assessed in relation to the facial midline, maxillary dental midline and midpoint of the chin. Although an incorrectly placed mandibular dental

midline is unlikely to adversely affect smile aesthetics, it is important to have coincident midlines to produce a well intercuspated dental occlusion.

Note

The maxillary dental midline should ideally be coincident with the facial midline. However, studies have demonstrated that maxillary dental midline discrepancies greater than 2–4 mm are generally unacceptable, implying that a small (<2 mm) midline discrepancy may be largely unnoticeable.²⁹ What is more noticeable than a small midline discrepancy is incorrect axial incisor angulation (Figure 23.21). Angulations of greater than 6° have been found to be unacceptable when judged by

orthodontists and greater than 10° when judged by laypeople.³⁰ It is therefore imperative that the maxillary incisors are correctly angulated, that the *mesial and distal contact areas of their crowns* are approximately *parallel to the facial midline* and that there is no transverse cant to the incisal edge plane, in order to avoid the *slanted* midline, which is considered unattractive (Figure 23.22).

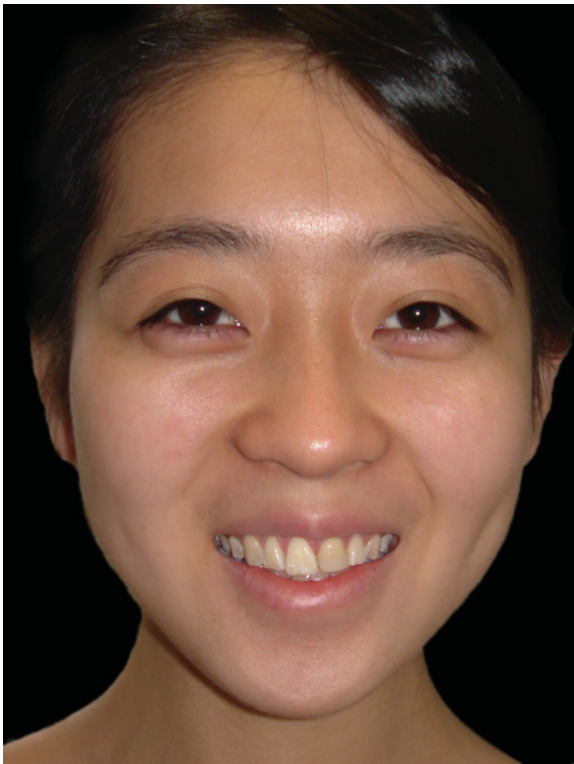


Figure 23.21 Incorrect maxillary incisor angulation is more noticeable than a bodily dental midline shift; in this patient, the maxillary incisors are angulated to her left.

Buccal corridors (negative space)

The **buccal corridor** or 'negative space' is the space revealed between the buccal surface of the posterior teeth and the commissures of the lips when a patient smiles (Figure 23.23). The presence of dark buccal corridors (excessive lateral negative space) may be due to:¹²

- **Transverse narrowing of the maxilla, especially in the premolar region:** When excessively narrow, expansion of the maxillary arch may be required in order to improve the arch form and dental occlusion; an additional advantage is that such expansion helps to fill the corners of the smile.
- **Palatal inclination of the maxillary posterior dentition:** The terminal tooth exposed in smiling is often the first or second premolar. As such, *it is important that maxillary premolar crowns are not palatally inclined*. Where this is the case, increased buccal crown inclination and/or expansion of the posterior maxillary dentition, primarily in the premolar region, are required. In aesthetic dentistry, an increase in the thickness of the buccal aspect of ceramic restorations on the premolar teeth may help to fill out the smile.
- **Retropositioned maxilla:** Maxillary advancement is the treatment of choice, as moving the maxilla anteriorly permits a wider part of the dental arch to move forward and reduce the lateral negative space (Figure 23.24).
- **Dynamic inter-commissure distance:** Normal values for inter-commissure distance (i.e. mouth width) in repose have been provided by Farkas:³¹
 - Male: 55 ± 3 mm
 - Female: 50 ± 3 mm.

Data on changes in mouth width in the dynamic state of smiling are limited.³² However, Rigsbee et al.³³ demonstrated that, in an 'attractive' smile, the mouth increased to 130% of its original width. There is likely to be considerable individual variation in the degree of increase in inter-commissure distance in smiling. The greater this increase, the greater the potential for lateral negative space in smiling.

- **The vertical dimension:** It has been demonstrated that an increased lower anterior face height (measured from subnasale to soft tissue menton) and, in particular, the lower lip-chin height (measured from stomion to soft tissue menton),

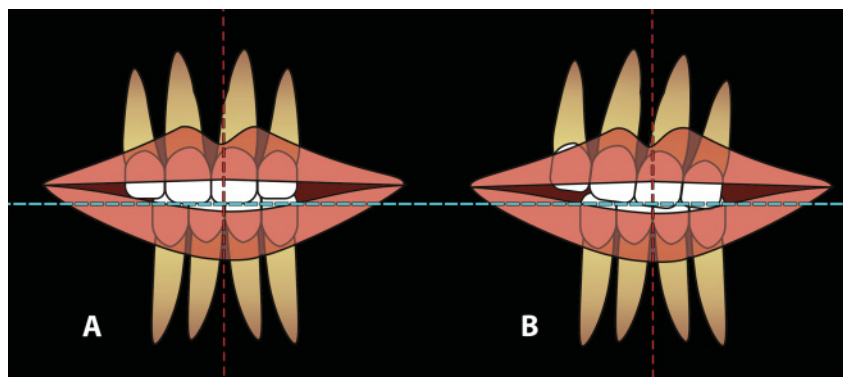


Figure 23.22 Maxillary dental midline shift of 2 mm to the right of the patient's facial midline. (A) The maxillary incisors are correctly angulated, with the mesial and distal contact areas of their crowns parallel to the facial midline. (B) Excessive maxillary incisor angulation to the patient's right and thereby a transverse cant of the incisal edge plane.



Figure 23.23 Absence of buccal corridors – the posterior dentition ‘fills’ the corners of the smile.

are negatively correlated with the **buccal corridor area**, i.e. the two-dimensional area visible in frontal view. This is thought to be due to increased stretch of the lower facial soft tissues in patients with increased lower face height, and thereby reduced buccal corridors in smiling.³⁴

Note

The **concealed premolar smile**: A great deal of attractiveness research has been carried out on the influence of buccal corridors on the perceptions of smile attractiveness. Orthodontists do not like buccal corridors, yet the results of research indicate that laypeople do not share this orthodontists’ dislike.³⁵ In denture prosthetics a degree of lateral ‘negative space’ (buccal corridors) is planned, and thought to give a more natural appearance. Overall, it is likely that the parameter leading to the perception of smile attractiveness is not the presence or absence of buccal corridors, but the *visibility of the posterior dentition distal to the maxillary canine teeth*. In patients with adequate visibility of the premolar teeth when observed in frontal view, the presence of buccal corridors is unlikely to be perceived as unattractive; conversely, in patients with a narrow ‘canine to canine’ smile with the premolars *concealed* behind the canine teeth (‘concealed premolar smile’), the smile attractiveness is likely to be unsatisfactory (Figure 23.25).

Smile aesthetics in profile view

The relationship of the maxillary incisors with respect to the facial profile is one of the cornerstones of facial aesthetic treatment planning. This relationship depends on the sagittal and vertical position of the maxillary central incisors in relation to the face and, importantly, on the *inclination of the labial face of the maxillary central incisor teeth*. The inclination of the maxillary incisors is important both in terms of occlusal function and dentofacial aesthetics.

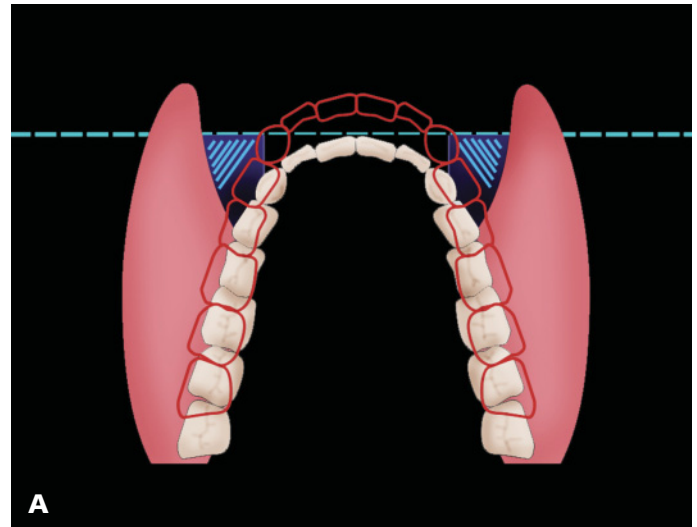


Figure 23.24 (A) Maxillary advancement permits a wider part of the dental arch to move forward and reduce the lateral negative space. (B) Buccal corridors evident in a patient with maxillary retrognathia. (C) Maxillary advancement has reduced the buccal corridors.

Note

Traditional cephalometric techniques of measuring maxillary incisor inclination depend on drawing the *long axis* of the *maxillary incisor* from the incisal tip to the root apex and extending this line to meet a reference plane (such as the maxillary plane, Frankfort Horizontal plane or sella-nasion plane) from which the incisor inclination may be measured (see Figure 7.33). There are four problems with this approach:

- **Variability of anatomical craniofacial reference plane:** The inclination of the maxillary incisors relative to any anatomical craniofacial reference plane will depend on the orientation of the reference plane, which is subject to *individual variability*.
- **Labial crown face inclination versus long axis inclination:** There may be significant variation between the inclination of the labial face of the maxillary incisor crown and the long axis of the maxillary incisor (Figure 23.26).
- **Crown-root angle:** Variation may exist in the crown-root angle of the maxillary central incisor teeth. The long axis of the maxillary incisor root is not always identical to that of the crown. Instead, there is appreciable variation in the crown-root angle, generally with the crown inclined palatal to the root axis (Figure 23.27).³⁶
- **High error in identifying the maxillary incisor apex:** The maxillary incisor apex is often a difficult point to identify on a lateral cephalometric radiograph.

Therefore, the most accurate measurement of maxillary incisor crown inclination is potentially that of a *tangent* to the *labial face* of the *maxillary central incisor* in relation to the *true horizontal plane*, with the patient in natural head position (Figure 23.28). Normative data for this approach is, as yet, unavailable.

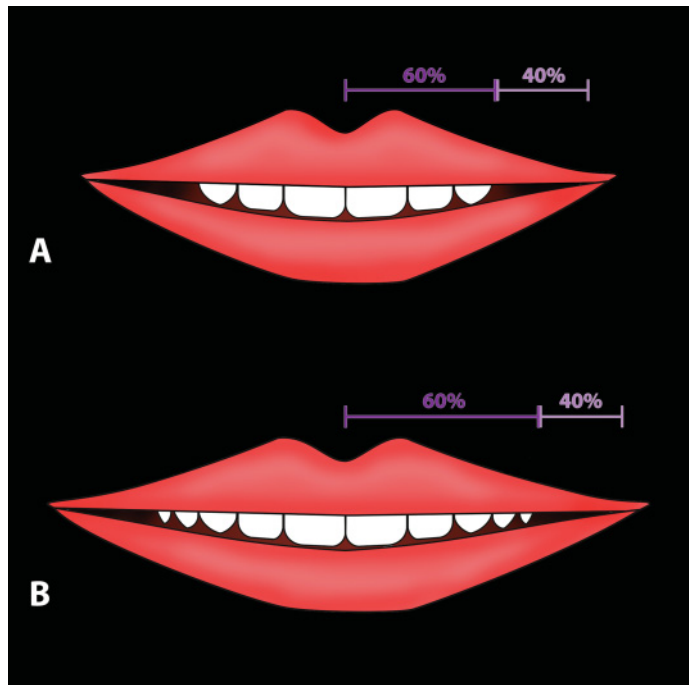


Figure 23.25 The 'concealed premolar' smile: it is likely that the parameter leading to the perception of smile attractiveness is not the presence or absence of buccal corridors, but the visibility of the posterior dentition distal to the maxillary canine teeth. **(A)** Narrow 'canine to canine' smile with the premolars 'concealed' behind the canine teeth. **(B)** Adequate visibility of the premolar teeth when observed in frontal view. In both situations, the percentage of visible dentition to buccal corridor is identical, but the visibility of the premolar teeth distal to the canines in **(B)** improves the smile aesthetics.

Excessive proclination of the maxillary incisors is unattractive and reduces incisor exposure in repose and in animation; it may also lead to a **traumatic occlusion** as a result of injury to the maxillary incisor periodontium from occlusal loading in a non-physiological direction (i.e. mandibular incisors striking the maxillary incisors at an incorrect angle, thereby not permitting the normal dissipation of occlusal forces). Excessive retroclination

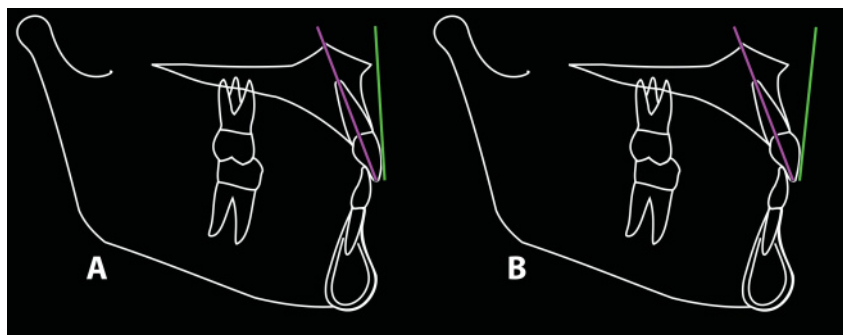


Figure 23.26 Variations between the inclination of the labial face of the maxillary incisor crown and the long axis of the maxillary incisor. In both **(A)** and **(B)** the inclination of the long axis of the maxillary incisors is identical, but the inclination of a tangent to the labial face is markedly different.



Figure 23.27 Variation from the norm in the crown-root angle of the maxillary central incisors. The long axis of the maxillary incisor root is markedly different from that of the crown.

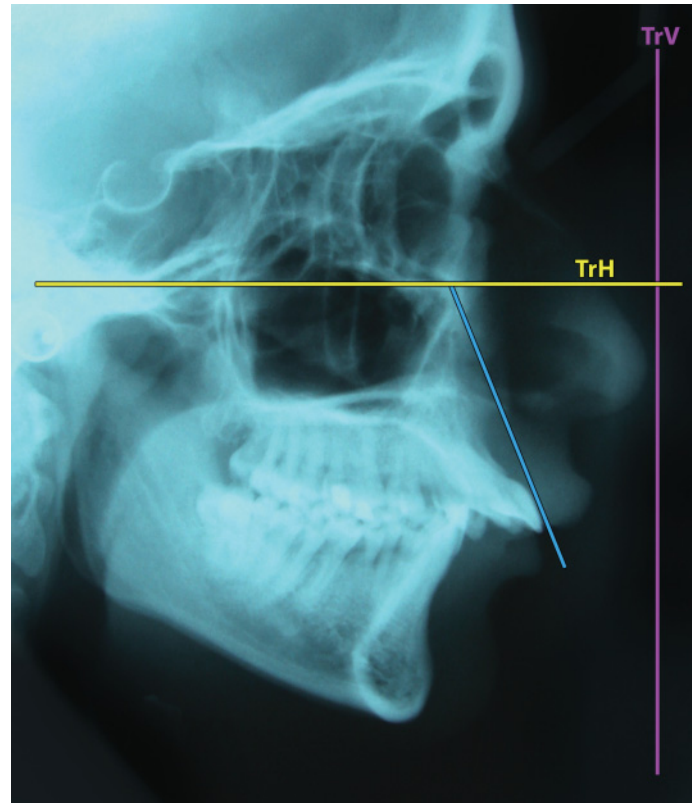


Figure 23.29 Excessive maxillary incisor proclination may be evaluated on a profile smiling photograph and a lateral cephalometric radiograph taken with the patient in natural head position. TrH, true horizontal; TrV, true vertical.



Figure 23.28 The most accurate measurement of maxillary incisor crown inclination is that of a tangent to the labial face of the maxillary central incisor in relation to the true horizontal plane (TrH), with the patient in natural head position. TrV, true vertical.

of the maxillary incisors is also unattractive, though incisor exposure may increase as a result of overeruption of the maxillary labial segment.

Fredericks³⁷ described the treatment objective of achieving a labial crown face inclination parallel to the facial plane (nasion-pogonion); however, the anatomic facial plane is subject to individual variability. Therefore, maxillary incisor crown inclination is ideally evaluated in a **facial profile smiling view** (and a lateral cephalometric radiograph) (Figure 23.29), with the patient in natural head position (NHP). *A tangent to the labial face of the maxillary central incisors should be parallel to the true facial vertical plane* (Figure 23.28).

Note

It is important to distinguish between maxillary incisor **protrusion** and **proclination**. Patients may present with maxillary dentoalveolar protrusion, proclination or a combination. Protrusion signifies an excessively forward sagittal position of the anterior dentoalveolus, whereas proclination signifies excessive forward inclination of the incisor teeth. Correction of maxillary incisor protrusion thereby requires bodily retraction, whereas proclination requires retroclination (rotation around the centre of resistance) to the correct inclination (see Chapter 16).

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Chapter 24 Dentogingival Aesthetics

Introduction

The dentogingival complex may be considered an aesthetic unit of the face, i.e. the **dentogingival aesthetic unit**, composed of the **gingival subunit** and the **dental subunit**.

Anatomy

The **teeth** occupy approximately one-fifth of the surface area of the oral cavity in adults. They serve the important functional role of **mastication** and are essential for proper **speech** and **dento-facial aesthetics**. In mammals, the teeth are attached to the supporting alveolar bone by a fibrous connective tissue, termed the **periodontal ligament** (PDL); the flexibility of the PDL within this structural relationship permits the teeth to withstand the considerable forces of mastication. In humans, the succession of the **primary (deciduous) dentition** by the larger and more numerous teeth of the **secondary (permanent) dentition** accommodate the substantial growth of the face and jaws.¹

Anatomically, the teeth consist of a **crown** and a **root**; the junction between the two is termed the **cervical margin**. The term **clinical crown** refers to the part of the crown visible in the oral cavity. The anatomical crown is covered by **enamel**, which is a hard, acellular and relatively brittle tissue; it is the most highly mineralized tissue in the human body (96% mineralized). Enamel would be unable to withstand the forces of mastication without fracture was it not for its support from the resilient underlying specialized connective tissue termed **dentine**. Dentine is a relatively hard (70% mineralized), avascular tissue; it is yellowish-white, which gives teeth their colour. It is sensitive and more importantly, capable of repair by the laying down of

secondary dentine by cells called **odontoblasts**, which initially form the dentine and subsequently line the periphery of the dental pulp. The dentine encloses the central **pulp chamber**, which is filled with a soft connective tissue called the **pulp**.

The oral cavity is lined by **oral mucosa** (oral mucous membrane), which is comprised of the following:²

- **Masticatory mucosa:** This covers the gingivae and the hard palate. It is tightly bound down to the underlying bone and the covering epithelium is heavily keratinized.
- **Specialized mucosa:** This covers the dorsum of the tongue and is similar to masticatory mucosa but contains papillae and taste buds.
- **Lining mucosa:** The remaining mucosa of the oral cavity is relatively mobile, i.e. the labial and buccal mucous membrane and the mucosa of the soft palate and pharynx.

The term **periodontium** (Greek *peri*:- around; *odontos*: tooth) refers to the supporting tissues of the teeth. It is comprised of the following component parts:

- **Gingiva:** This refers to the part of the masticatory mucosa that covers the alveolar process and surrounds the cervical portion of the teeth. The gingiva is comprised of two parts:
 - **Free gingiva** (Figure 24.1): Healthy free gingiva is pink in colour and has a firm, smooth consistency. It comprises the buccal, lingual and interdental gingival tissue and the interdental **papillae**. On the buccal and lingual side of the teeth the free gingiva extends from the **free gingival margin** apically towards the **free gingival groove** (only visible in 30–40% of adults), which is positioned at a level corresponding to the **cemento-enamel junction** (CEJ).

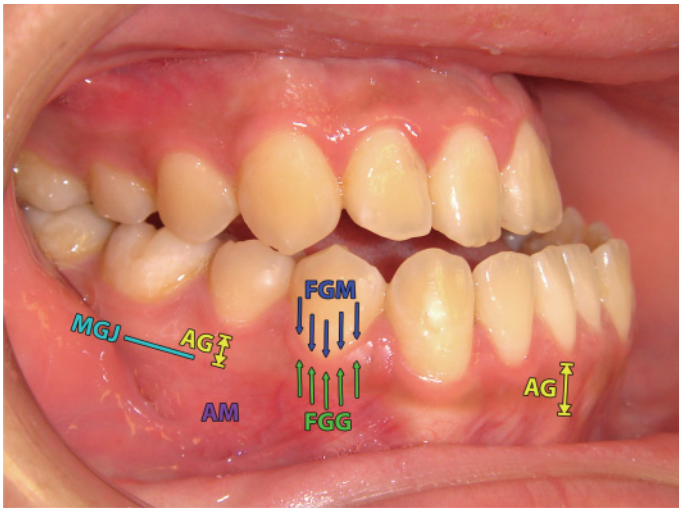


Figure 24.1 Gingival anatomy. The free gingiva extends from the free gingival margin (FGM) apically to the free gingival groove (FGG), which is positioned at a level corresponding to the cemento-enamel junction. The attached gingiva (AG) extends from the free gingival groove region to the mucogingival junction (MGJ), where it becomes continuous with the lining alveolar mucosa (AM) of the oral cavity.

The typical scalloped gingival margin contour runs parallel to both the underlying osseous crest and the CEJ. In fully erupted teeth, the free gingival margin is located 0.5–2 mm coronal to the CEJ.² In healthy gingivae, the free gingiva is in close contact with the tooth enamel surface, though it is possible to gently probe the **gingival sulcus** (or gingival crevice) in the enamel–gingiva interface approximately to the level of the CEJ.

- **Attached gingiva:** This extends apically from the free gingival groove or, when such a groove is not present, from a horizontal line level with the CEJ, to the **mucogingival junction**, where it becomes continuous with the lining **alveolar mucosa** of the oral cavity. Healthy attached gingiva is pink in colour and may exhibit an 'orange peel-like' stippled appearance in some individuals. It is firmly attached to the alveolar bone and relatively immobile compared with the loosely bound and darker alveolar mucosa.
- **Periodontal ligament:** This is the soft, richly vascular and cellular connective tissue that surrounds the roots of the teeth, connecting the root cementum to the alveolar bone of the tooth sockets. The PDL space is about 0.2 mm in width and contains sensory receptors.
- **Root cementum:** This is the specialized calcified tissue (50% mineralized) covering the root surfaces of the teeth.
- **Alveolar bone:** This is the bone of the alveolar process of the maxilla and mandible that forms and supports the sockets of the teeth. It is firmly attached to the basal bone of the jaws. It is important to bear in mind that the alveolar process forms in relationship to the teeth; as such, tooth loss results in eventual resorption of the alveolar process. This is

particularly evident in edentulous patients whose chin and nose approximate as a result of alveolar bone resorption and subsequent reduction in lower anterior face height.

Note

If there is resorption of the alveolar bone at the coronal aspect of the roots, the exposed root is termed a **dehiscence**. If there is some alveolar bone coronal to the exposed root, the exposed root is termed a **fenestration**. Excessive orthodontic arch expansion in the sagittal or transverse plane may lead to root dehiscence with associated gingival recession. Excessive buccal root movement (buccal root torque) may lead to root fenestration, which may be palpable and sometimes even visible under the buccal mucosa.

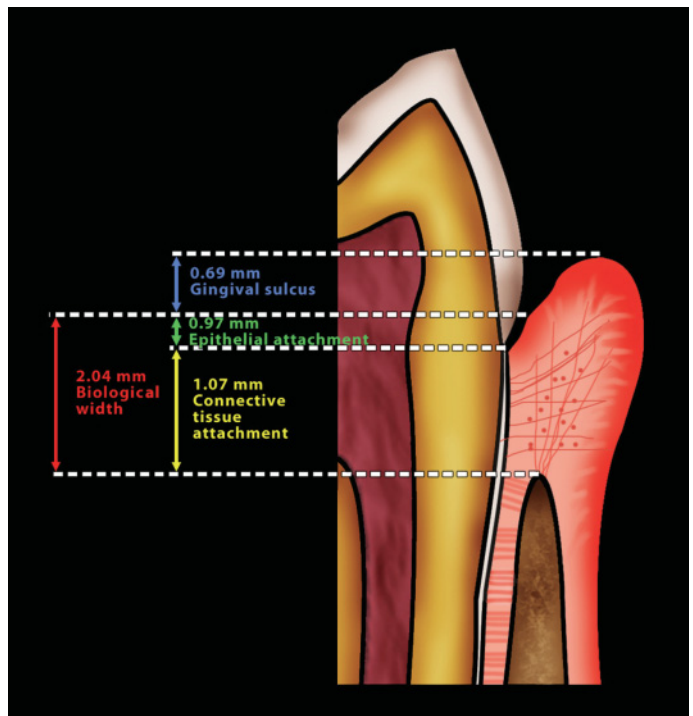


Figure 24.2 The dentogingival unit and 'biological width'.

The existence of the PDL as a **functional unit** together with the root cementum and alveolar bone is the reason orthodontic forces are able to move teeth through the supporting alveolar bone. It is much more difficult to modify the position of the basal bone of the maxilla and mandible. This may be achieved to an extent by attempting to modify jaw growth; otherwise altering basal bone position or morphology requires corrective jaw surgery (orthognathic surgery).

The concept of 'biological width'

A cross-section of the dentogingival unit reveals that it is composed of three parts. Gargiulo et al.³ analysed autopsy specimens to calculate the vertical depth of each of these parts. From an occlusal to apical direction, these are (Figure 24.2):



Figure 24.3 Maxillary incisor crown shape: (A) ovoid (barrel-shaped); (B) rectangular; and (C) triangular.

- **Gingival sulcus:** 0.69 mm
- **Epithelial attachment (also termed the junctional epithelium):** 0.97 mm; this epithelial attachment is from the CEJ onto the tooth enamel.
- **Supracrestal connective tissue attachment:** 1.07 mm; these connective tissue fibres emanate from the osseous crest to the CEJ.

The combination of the linear height of the epithelial and the connective tissue attachment (2.04 mm) has been termed the **biological** (or **biologic**) **width**.⁴ This may be defined as the *combined width of connective tissue and junctional epithelial attachment formed adjacent to a tooth and superior to the crestal bone*.

The biological width has been demonstrated to be remarkably consistent; conversely, the gingival sulcus depth is highly variable. The biological width is three-dimensional and surrounds every tooth; hence the alternative suggested term is 'biological zone'. This zone acts as a natural barrier, protecting the PDL and the alveolar bone from the ingress of pathogens; bacterial ingress may thus lead to periodontal disease. Dental restorative procedures must also respect this 'zone' in order to maintain a healthy periodontium; impingement of the margins of restorations into the biological width results in inflammation, loss of epithelial attachment, apical migration of the junctional epithelium and thereby periodontal pocket formation.

Clinical evaluation

The *position* of the maxillary incisor crowns in relation to the face in the evaluation of dentofacial aesthetics has been described. The *shape* and *size* of the maxillary incisor crowns forms the starting point in the clinical evaluation of dentogingival aesthetics.

Note

Aesthetic dental evaluation requires clinical evaluation from the **frontal view**, i.e. the clinician must be positioned in front of the patient and *not* just observing from above and behind. Frontal evaluation of the anterior dentition is a prerequisite for accurate diagnosis.

Tooth shape

The morphology of the maxillary incisor crowns, as observed in frontal view, involves the amalgamation of the *three basic geometrical shapes*, i.e. the circle, square and triangle, from which any shape may be created. Tooth shape is **genetically determined** and there is considerable **individual variability**. The overall shape of the crowns of the maxillary incisor teeth in each individual will fit predominantly into one of the following categories (Figure 24.3):

- **Ovoid:** combination of circle and square/rectangle.
- **Rectangular:** elongated square.
- **Triangular.**

Note

The teeth of most animals are all the same shape (**homodont**), but in most mammals, including humans, they are different (**heterodont**); human teeth fall into three groups (see Chapter 21):

- **Incisiform** (central and lateral incisors).
- **Caniniform** (canines).
- **Molariform** (premolars and molars).

Tooth morphology is remarkably consistent.⁵ When aberrations in the shape of teeth do occur, most commonly in the maxillary lateral incisor crown, which may be **peg-shaped** or **diminutive**, and the third molars, it is as a result of some effect early in the developmental history of the tooth. In fact, the crown pattern of each tooth is determined during the **bell stage** of dental development.¹

Theories of 'ideal' tooth shape

A number of theories have been proposed regarding maxillary incisor crown morphology:

- **Tooth shape–face shape correlation:** In 1887, Ivy⁶ proposed the **temperamental theory**, which suggested that an individual's *personality* influenced the morphology of the teeth. Williams^{7–9} dismissed the temperamental theory, proposing that the shape of the maxillary central incisor crown was related to the inverted frontal view of the face, the so-called **geometric theory**. This theory was also subsequently invalidated, but led to the work of House and Loop.¹⁰

- **Tooth width–face width correlation:** House and Loop¹⁰ described the relationship between the width of the maxillary central incisor crown and the bizygomatic facial width, with a ratio of 1 to 16. LaVere et al.¹¹ subsequently confirmed this finding. *Such a correlation may not be absolutely accurate, but is a useful starting point* (Figure 24.4).
- **Sex, age and personality (SAP) theory:** Frush and Fisher (1955)¹² suggested a correlation between the sex, age and personality of an individual and the shape of the maxillary incisor and canine teeth; this concept was originally proposed for guidance in tooth selection for denture aesthetics (Figure 24.5).
 - **Sex:** The feminine facial form tends to display ‘soft’ curvilinear relationships and is devoid of sharp line angles, whereas masculine faces tend to have increased angularity. Accordingly, the shapes of the maxillary incisor crowns in women tend to be ‘softer’, with rounded angles.¹³
 - **Age: Attrition** may be defined as tooth surface loss (**tooth wear**) due to repetitive physiological or parafunctional occlusal contact between the teeth. In younger individuals, the incisal edges of the maxillary incisor teeth are unworn, and may present with **mamelons**, which usually appear as three small rounded prominences on the incisal edges of the incisor teeth (Figure 24.6). Tooth wear from attrition results in a reduction in

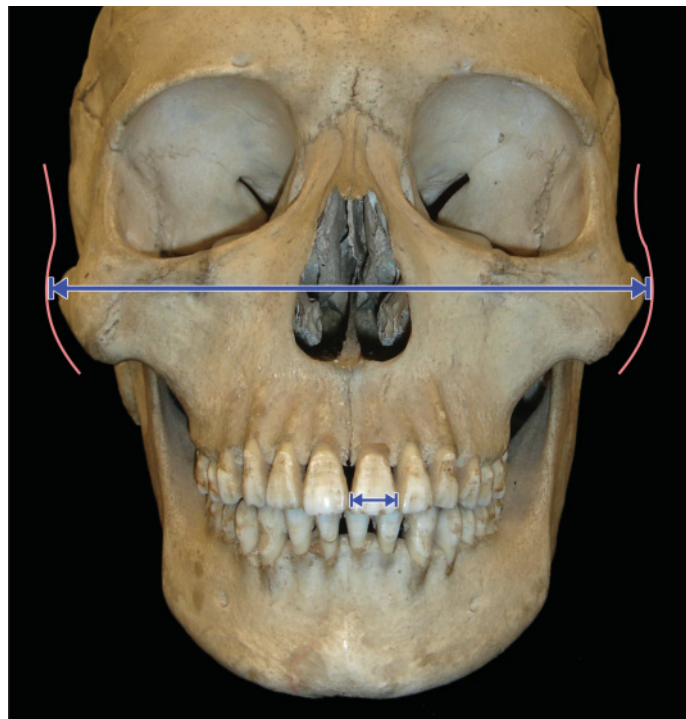


Figure 24.4 Tooth width–face width ratio: maxillary central incisor crown width to bizygomatic facial width ratio has been described as approximately 1 to 16.^{10,11}

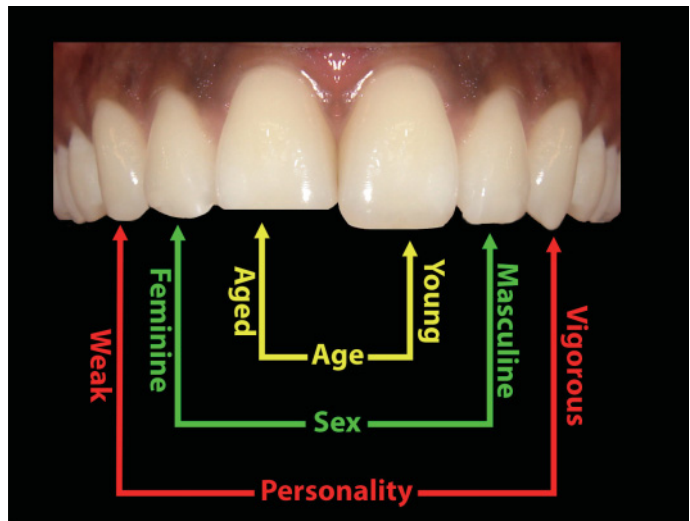


Figure 24.5 SAP (sex, age and personality) theory.¹²



Figure 24.6 Mamelons usually appear as three small rounded prominences on unworn incisal edges.

incisor crown height, which often accompanies the ageing process. However, the aetiology of tooth wear is multifactorial, and younger individuals may present with excessive attrition. Conversely, older individuals with anterior open bites may still possess mamelons. Elderly individuals are sometimes described as being ‘long in the tooth’. This is partly due to buccolabial gingival recession, which has a multifactorial aetiology, but is correlated with increasing age (Figure 24.7).

- **Personality:** The concept suggests that individuals with extrovert personalities may be better suited to increased incisor exposure with brighter teeth, as opposed to introverts. This concept is not evidence based and remains debatable.



Figure 24.7 Gingival recession has exposed the root surfaces, which show signs of abrasion.

Note

Despite the numerous tooth selection theories described over more than a century, *none is completely reliable or accurate*. Facial shape, as suggested by Williams⁷⁻⁹ and House and Loop¹⁰, is still used by some clinicians as a starting point in aiding the selection of maxillary central incisor crown shape in denture prosthetics and prosthodontic treatment. Nevertheless, it is important to bear in mind that recent research evidence has found *no* statistically or clinically significant association between face shape and maxillary central incisor crown shape¹⁴⁻¹⁶ and *no* significant correlation between tooth form and sex.¹⁶

Tooth size

Tooth size is genetically determined. Tooth size does not necessarily correlate well with standing height or stature, i.e. a tall individual may have small teeth. However, men tend to have larger teeth than women, and black individuals tend to have larger teeth than Caucasians.¹⁷ Maxillary incisor **crown size** may be measured as the mesiodistal width, the inciso-gingival height and the width-to-height ratio. Various authorities have provided data on maxillary incisor crown dimensions in Caucasian individuals, from which are derived the following 'average' dimensions:

- **Average crown width:** 8–9 mm.
- **Average crown height:** 10–11 mm.

Width-to-height ratio of maxillary central incisor crown

The average width-to-height ratio of the maxillary central incisor crown is 0.75 to 0.8, i.e. the crown width should be 75–80% of its height (Figure 24.8). A ratio of less than 60% creates a tall narrow crown, whereas a ratio greater than 85% results in a short wide crown appearance. This *ratio is more important than the component crown width or height*.

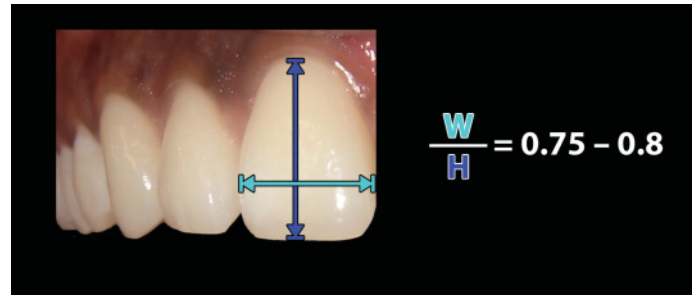


Figure 24.8 The width-to-height ratio of the maxillary central incisor crown is more important than the component crown width or height.

Note

It is worth noting that **optical concepts** play a part in the perceived size and shape of the anterior teeth. Maxillary incisors of reduced height will *appear* wider (Figure 24.9); this *optical illusion* is particularly evident in patients with excessive incisal attrition. It is also evident that whiter, brighter teeth *appear* larger and more prominent than darker teeth (Figure 24.10).¹⁸



Figure 24.9 Optical concepts: maxillary incisors of reduced height will *appear* wider.

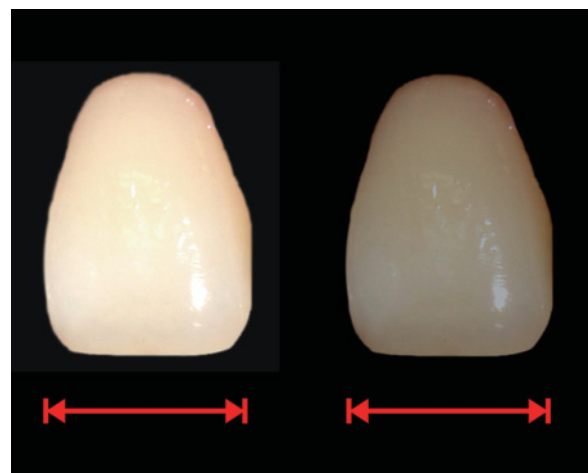


Figure 24.10 Optical concepts: whiter, brighter teeth *appear* larger and more prominent than darker teeth.

Seventh key and dental occlusion

Tooth size is described as the seventh key to 'ideal' dental occlusion, the other six morphological characteristics of an 'ideal' occlusion represented as Andrews' six keys (i.e. Class I molar relationship, correct crown angulation and inclination, no rotations, no spaces and a level curve of Spee) (see Chapter 22). The presence of a **tooth size discrepancy** will either result in a spaced dentition or a less than ideal dental occlusal relationship.

Tooth size analysis

For 'ideal' dental aesthetics, the anterior teeth must be proportional in size as described above. Additionally, for 'ideal' dental occlusion, the maxillary and mandibular teeth must have a certain proportionate relationship in terms of size. It will not be possible to achieve an 'ideal' occlusion if individual teeth or groups of teeth in the maxillary or mandibular arches are either too large or too small compared with their antagonists in the opposing dental arch. Such a discrepancy is termed **tooth size discrepancy**.

Evaluation of tooth size is an important part of clinical diagnosis. **Tooth size analysis** (also termed a **Bolton analysis** after its development in 1958 by the orthodontist Wayne Bolton) may be undertaken by measuring the mesiodistal widths of either the anterior teeth (canine to canine) or the entire arch (first molar to first molar, excluding second and third molars).¹⁹ A table of standard values (Table 24.1; based on Caucasian values) lists the summed tooth width value in the opposing arch that is ideally related to the measured value, i.e. it is used to compare the summed widths of the maxillary with the mandibular anterior teeth (**anterior Bolton ratio**) or the summed widths of the entire maxillary to the mandibular arch (**overall Bolton ratio**).²⁰ The difference between the 'ideal' value from the standard table and the actual measured dental width in the *arch with the excess value* provides an estimate in millimetres of the extent of tooth size discrepancy.

It has been demonstrated that a significant number of patients have a tooth size discrepancy of *greater than 2mm*, which is clinically significant as it may affect the dental occlusion. Additionally, simple visual estimation has been shown to be inaccurate at determining a tooth size discrepancy.²¹

Note

Tooth size analysis should be undertaken for patients prior to orthodontic treatment. Prior to this, at the initial clinical examination stage, two straightforward interarch comparisons may be undertaken:

- **Lateral incisor width:** The maxillary lateral incisors should be wider than the mandibular; if the maxillary lateral incisors are the same size as or smaller than the mandibular, there is an *anterior* tooth size discrepancy (Figure 24.11).
- **Second premolar width:** The maxillary and mandibular second premolars should be approximately the same mesiodistal width; a discrepancy in size may indicate a *posterior* tooth size discrepancy.

Table 24.1 Tooth size analysis (Bolton analysis) standard table of values

Maxillary anterior 3–3 summed widths (mm)	Mandibular anterior 3–3 summed widths (mm)	Maxillary total 6–6 summed widths (mm)	Mandibular total 6–6 summed widths (mm)
40	30.9	86	78.5
41	31.7	88	80.3
42	32.4	90	82.1
43	33.2	92	84.0
44	34.0	94	85.8
45	34.7	96	87.6
46	35.5	98	89.5
47	36.3	100	91.3
48	37.1	102	93.1
49	37.8	104	95.0
50	38.6	406	96.8
51	39.4	408	98.6
52	40.1	110	100.4
53	40.9		
54	41.7		
55	42.5		

Tooth proportions

Three important proportional relationships may be considered in dental aesthetic analysis:

- **Maxillary central incisor crown width-to-height ratio:** Already described above, the 'ideal' width-to-height ratio of the maxillary incisor crowns is approximately 0.75–0.8.
- **Tooth width to face width proportion:** Already described above, the relationship between maxillary central incisor crown width and bizygomatic facial width fits an approximate ratio of 1:16.
- **Maxillary incisor and canine crown width proportional relationship:** The third and important proportional relationship is that of the maxillary incisor and canine widths in relation to one another, *as observed in frontal view*. The curvature of the dental arch means that the *actual* incisor and canine widths and the *apparent* observed widths differ. That is, due to the curvature of the dental arch a decreasing amount of each tooth is displayed as the observer's eye progresses distally; this is termed **regressive proportion**. The entire central incisor crown is seen in frontal view, whereas the



Figure 24.11 The diminutive maxillary lateral incisor is narrower than the mandibular.

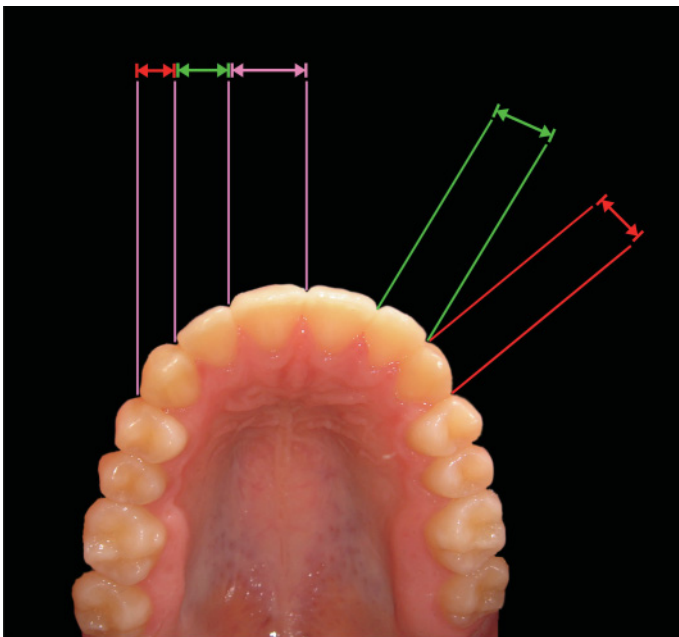


Figure 24.12 Due to the curvature of the dental arch a decreasing amount of each tooth is displayed as the observer's eye progresses distally; the actual width of the lateral incisor and canine is greater than their apparent observed widths in frontal view.

lateral incisor will be viewed as slightly narrower than its actual width due to its position on the dental arch and only the mesial portion of the canine crown is visible in frontal view (Figure 24.12). Lombardi²² and Levin²³ have suggested that the **golden proportion** may be used to evaluate the 'ideal' aesthetics of this **visual relationship**, i.e. if the *apparent* width of the maxillary lateral incisor is 1, the *apparent* width of the central incisor will be 1.618 (approximately 62%) times wider and the canine 0.618 times narrower (Figure 24.13).

It has been suggested that the golden proportion be used as a 'starting point' in designing the relative widths of the maxillary anterior teeth. Snow²⁴ has suggested applying the golden proportion to the total maxillary canine-to-canine width in order to create the **golden percentage**, with the following percentage

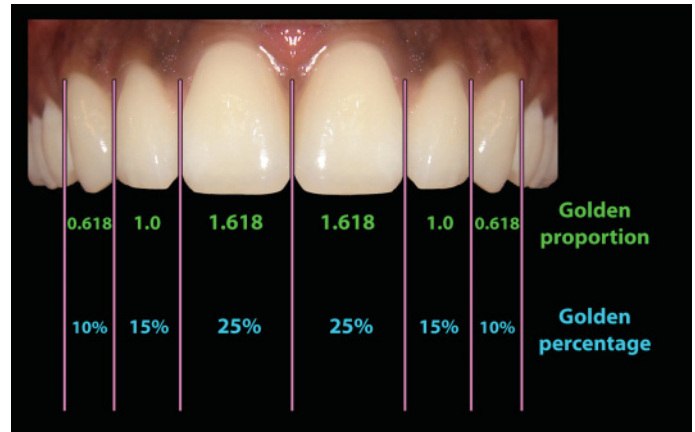


Figure 24.13 The golden proportion and golden percentage.

apparent widths from the right to the left canine: 10%:15%:25%:25%:15%:10%. That is, the *apparent* width of both the maxillary central incisors is 50% of the apparent canine-to-canine smile width. The advantage of the golden percentage over the golden proportion is deemed to be that it does not depend on the width of the maxillary lateral incisor but evaluates the width of each tooth relative to the entire labial segment and that any right-left asymmetry in apparent tooth widths is clearly identifiable.

Another variation of the golden proportion is the 'recurring aesthetic dental proportion' concept, which states that the successive *apparent* widths of the teeth as observed in frontal view should remain in a constant proportion, but not necessarily the golden proportion.²⁵

Note

There are two problems with the use of the golden proportion. Firstly, it takes no account of the crown height or width-to-height ratio and thereby no account of the morphology of the incisor teeth. Secondly, it will vary with variations in the shape of the dental arch, e.g. there will be greater lateral incisor and canine display in a wide, square arch form as a result of a more facial orientation of the anterior teeth compared with a narrow, tapering arch form (Figure 24.14); the relative width proportion of the maxillary anterior teeth ultimately depends upon the **arch form**, which is a critical factor in determining anterior tooth width proportions.²⁶

Analysis of the proportions of 'beautiful' smiles²⁷ and 'natural' smiles²⁸ has found that the majority did not coincide with the golden proportion. Furthermore, Bukhary et al.²⁹ found no evidence to suggest that the golden proportion should be considered the ideal aesthetic standard when creating space for the replacement of missing maxillary lateral incisors. The concept of an 'ideal' number related to dental aesthetics seems to be both ambiguous and misleading; it is certainly not surprising that *optimum aesthetics cannot be achieved by the application of a simple mathematical formula*.

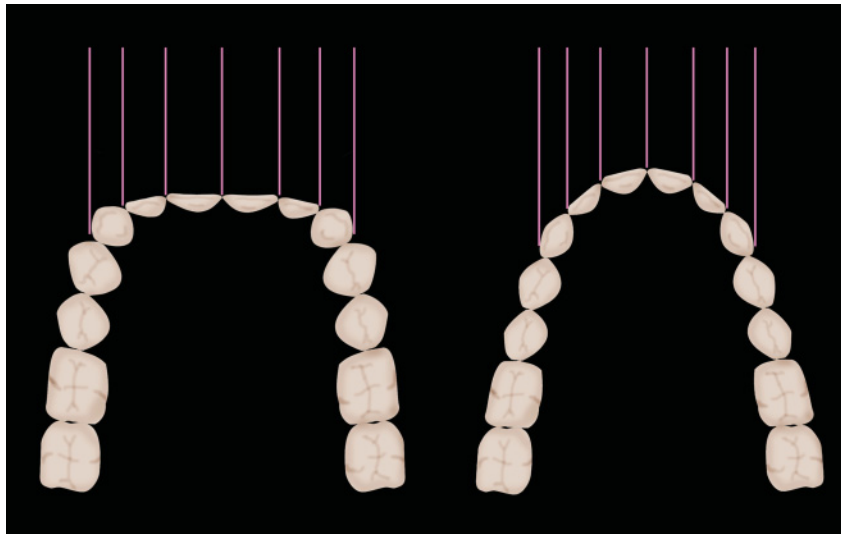


Figure 24.14 The golden proportion will vary with variations in the shape of the dental arch: there is greater lateral incisor and canine display in a wide, square arch form as a result of a more facial orientation of the anterior teeth compared with a narrow, tapering arch form.



Figure 24.15 Megadont maxillary central incisor – bilateral symmetry between the maxillary central incisors is paramount and in this situation difficult to achieve without removal of the megadont incisor and prosthodontic restoration.

Tooth symmetry

Symmetry may be defined as correspondence in size, shape and relative position of parts on opposite sides of a dividing line or median plane, which for the teeth is the dental midline. Asymmetry is defined as a lack or absence of symmetry. In terms of dental aesthetics, bilateral symmetry is important, becoming less important as one travels posteriorly in the dental arch. For example, symmetry between the maxillary central incisor crowns is very important, as they are the most obvious teeth and occupy the central position in the smile. Asymmetry between the maxillary central incisor crowns may be very noticeable (Figure 24.15). Kokich et al.³⁰ found that a small degree of asymmetry in the width of the maxillary lateral incisors may be largely unnoticed, though this is likely to depend on the patient's

arch form. Overall, left-right symmetry in the maxillary incisor and canine region is important in dental aesthetics (Figure 24.16).

The unilaterally peg-shaped or congenitally absent maxillary lateral incisor

The maxillary lateral incisor is often unilaterally peg-shaped or congenitally absent. Such patients will require orthodontic treatment to create the ideal size space for restoration, or space closure resulting in the maxillary canine next to the central incisor. Either way, the anterior dentition must be made symmetrical. If only one lateral incisor is missing or peg-shaped the lateral incisor that is present may be used as a guide to decide how much space should be created for the absent/abnormally shaped tooth. However, if both teeth are missing or misshapen the decision concerning how much space should be created is determined by aesthetic factors and the dental occlusion.³¹ *Aesthetically*, the lateral incisor should be approximately two-thirds of the width of a central incisor.³² Therefore, if a central incisor is 9 mm wide, the lateral incisor should be approximately 6 mm wide. *Occlusally*, if the correct posterior intercuspation is produced along with a normal overjet and overbite, the space for the lateral incisor may still be less than ideal in the presence of a **tooth size discrepancy**.

A tooth size discrepancy occurs if there is disparity between the sums of the mesiodistal tooth widths of sets of corresponding maxillary and mandibular teeth. In such cases interproximal enamel reduction may be undertaken on the distal surface of the central incisor and mesial surface of the canine in order to create the correct amount of space. When planning such cases it may be of great benefit to prepare a **diagnostic set-up** (also termed a **Kesling set-up** after the American orthodontist Harold Kesling); this is a laboratory procedure in which the teeth are cut from a duplicate set of plaster dental study casts and

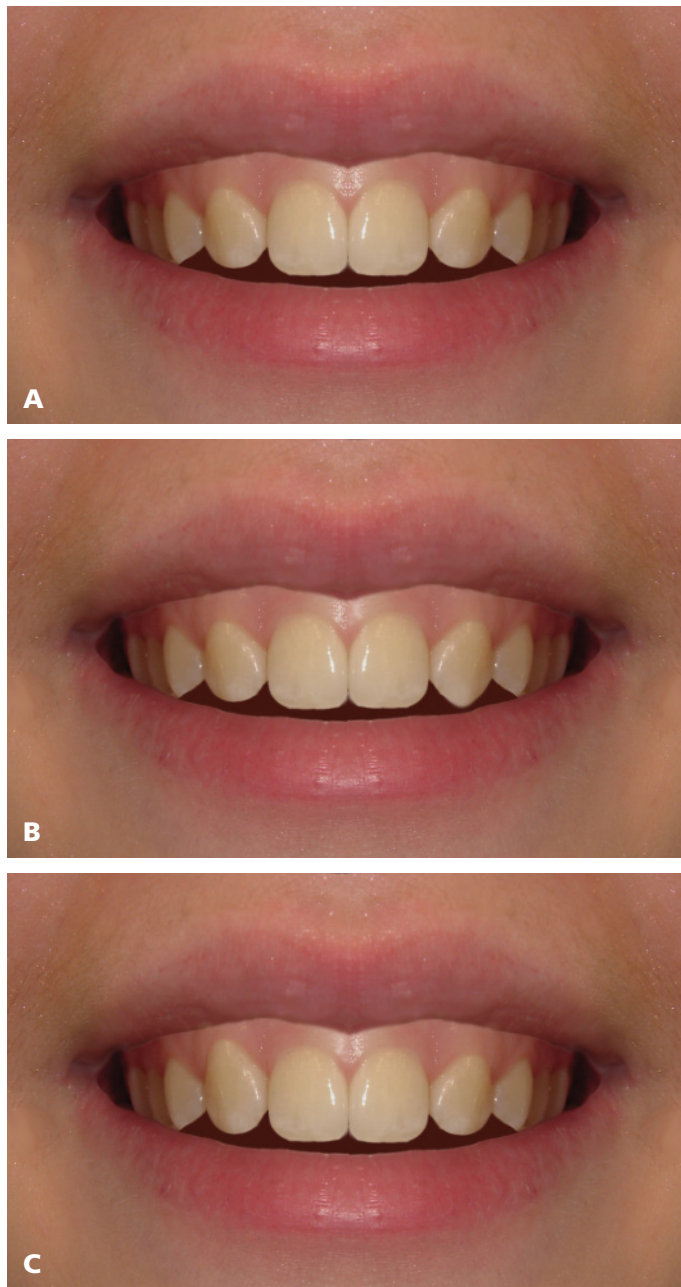


Figure 24.16 Maxillary canines substituted for missing lateral incisors bilaterally. (A) Bilateral symmetry. (B) Tip height and morphology asymmetry. (C) Gingival height asymmetry.

realigned in the desired position, in order to evaluate the predicted aesthetic and occlusal result from the proposed treatment. It is essential that a joint orthodontic-restorative opinion is sought when planning such cases and that a final restorative opinion is obtained before finally removing fixed orthodontic appliances to ensure that the correct amount of space is present between both the crowns and also the roots of the teeth if dental implant treatment is to be considered in the future.

Arch form

Dental arch form and arch dimensions exhibit considerable individual variability. Orthodontic expansion or contraction of the maxillary and mandibular dental arches is possible to a certain extent, mainly dependent on the width of the supporting alveolar bone. However, there is well-founded evidence that the teeth tend to assume a 'natural' position within the arch, within what is termed the **zone of soft tissue equilibrium**, which signifies a position of relative stability between the forces from the musculature of the lips/cheeks and the tongue (see Figure 22.25).³³ Significant movement of the teeth outside the limits of this 'zone' leads to instability. Therefore, where possible, the patient's original pretreatment arch form should be maintained, or at least not inordinately altered.

Note

The pioneering orthodontist Allan G Brodie (1897–1976) recognized and described the relationship between the orofacial musculature and tooth position.³⁴ This concept was experimentally verified by Weinstein et al.³³ who concluded that the teeth are maintained in a state of equilibrium between the perioral soft tissue forces. Proffit³⁵ revisited the **equilibrium theory**, noting that the *primary factors* involved in maintaining tooth position within the arch were the **resting pressures** of the lips, cheeks and tongue and the eruptive forces on the teeth. *Secondary factors* were head posture and jaw growth rotations, which altered and eventually re-established the zone of soft tissue equilibrium. Pressure from *extrinsic factors*, such as digit sucking habits or orthodontic forces, may lead to tooth movement by altering this equilibrium provided that the pressure is sustained for at least 6 hours per day.

Dental arch form may be arbitrarily classified as **square**, **ovoid** or **tapered**, albeit with a myriad of intermediate combinations (Figure 24.17). An understanding of arch form is required in orthodontic and prosthodontic diagnosis and treatment planning. The mandibular and maxillary dental arch forms should be symmetrical and coordinated with each other and, as far as possible, be concordant with the form of the respective skeletal basal bone. Greater arch form alteration requires orthognathic surgical procedures, such as surgically assisted rapid maxillary expansion.

Maxillary incisor axial angulations

The term **axial angulation** refers to the angular deviation of the long axis of a tooth from a line perpendicular to the occlusal plane, in a *mesiodistal* direction (Figure 24.18). In orthodontics, the mesiodistal axial angulation of the crown is also termed 'tip', particularly when referring to the angulation built into the

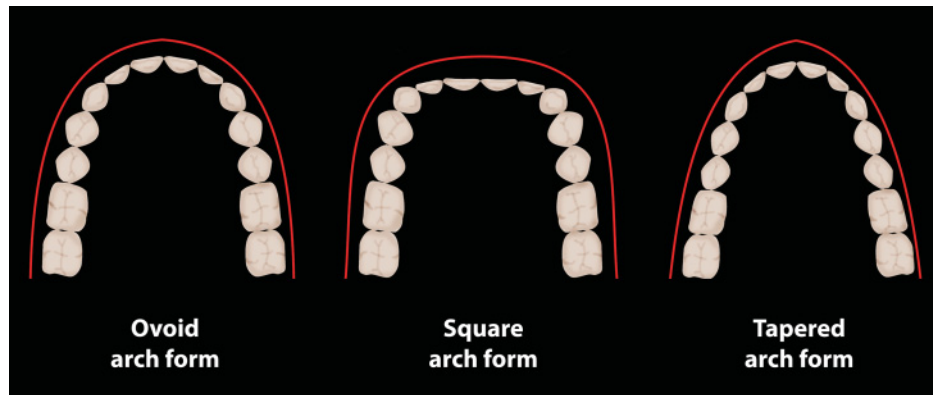


Figure 24.17 Dental arch form types may be arbitrarily classified as square, ovoid or tapered, albeit with a myriad of intermediate combinations.



Figure 24.18 Axial angulation refers to the angular deviation of the long axes of the teeth from a line perpendicular to the occlusal plane, in a mesiodistal direction. The long axes of the teeth have a variable degree of mesial angulation.

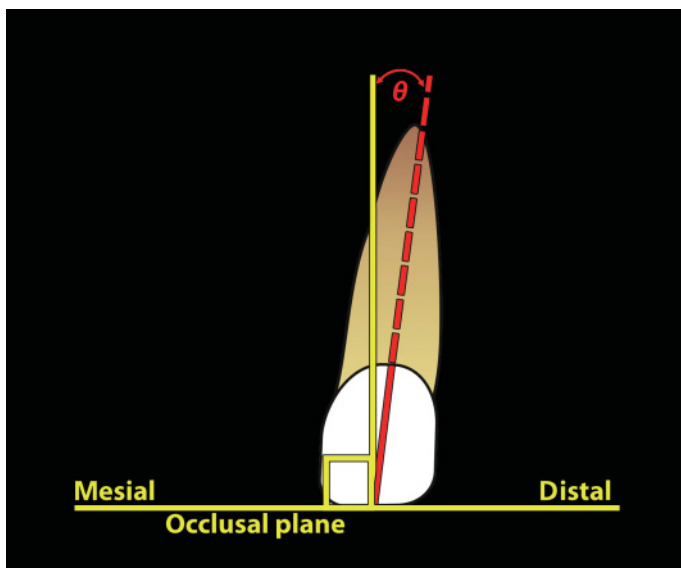


Figure 24.19 Incisor crown angulation ('tip') is measured by the angulation of the long axis of the **clinical crown** to a line perpendicular to the occlusal plane.

orthodontic bracket slot, to which a tooth crown will 'tip' when an orthodontic archwire is ligated into the bracket slot.

The **long axis** of the maxillary central incisors has a slight mesial angulation, i.e. the crown is angulated mesially and the root apex distally. The lateral incisors have a slightly greater mesial angulation and the canines an even greater mesial angulation. In terms of anterior aesthetics, the **crown angulation** is more important than the long axis angulation (Figure 24.19). In orthodontic treatment, the degree of mesial crown angulation depends on the **prescription** built into the orthodontic brackets; an example of the built-in 'tip' is 5° for the maxillary central incisor, 9° for the lateral incisor and 11° for the canine.

In frontal view, this mesial crown angulation becomes more pronounced from the central incisors towards the canines (Figure 24.20).

Gradation (front-to-back progression)

If two similar objects are placed at different distances from an observer, the object furthest away will appear the smallest. If a number of similar objects are placed at progressive distances

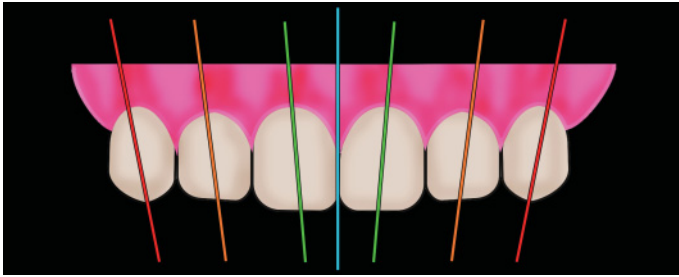


Figure 24.20 The anterior crown angulations have a general mesial angulation, which becomes more pronounced from the central incisors towards the canines.



Figure 24.21 In frontal view, the observer perceives a bilateral progressive reduction in the apparent size of the teeth from the most anterior to the most visible posterior teeth, termed the **gradation effect** or **front-to-back progression**.

between these two objects, the observer will perceive an *apparent* reduction in size from the closest to the furthest object. This visual phenomenon is termed the principle of **gradation**.¹⁸

In frontal view, the observer perceives a bilateral *progressive reduction* in the *apparent* size of the teeth from the most anterior to the most visible posterior teeth (Figure 24.21). This **gradation effect** or **front-to-back progression** depends on four parameters:

- **Buccal contour of the canine and premolar teeth:** The buccal contour of the maxillary canine and premolar teeth should be aligned and parallel, i.e. a tangent to the incisal third of the canine should be viewed as parallel to tangents to the incisal thirds of the premolar teeth. Tangents to the

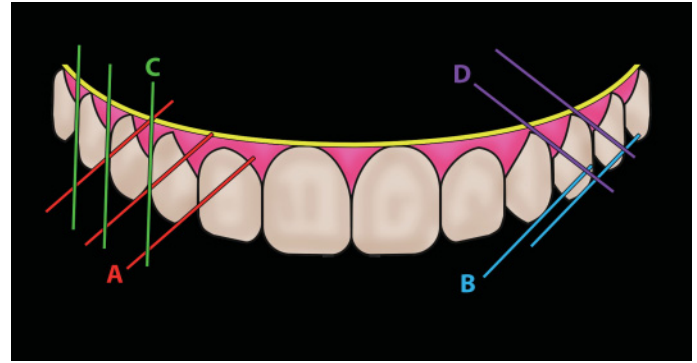


Figure 24.22 The aesthetic smile often demonstrates a gradation effect, i.e. a natural front-to-back progression of the size, morphology, positional relationships and colour of the teeth as the observer's eye moves from the anterior to the posterior teeth. The buccal contour of the maxillary canine and premolar teeth should be aligned and parallel: (A) tangents to the palatal contour of the buccal cusps should be approximately parallel; (B) tangents to the buccal contour of the buccal cusps should be approximately parallel; (C) tangents to the mid-third of the canine and premolars should be aligned parallel; and (D) tangents to the gingival thirds of the canine and premolars should be aligned parallel.

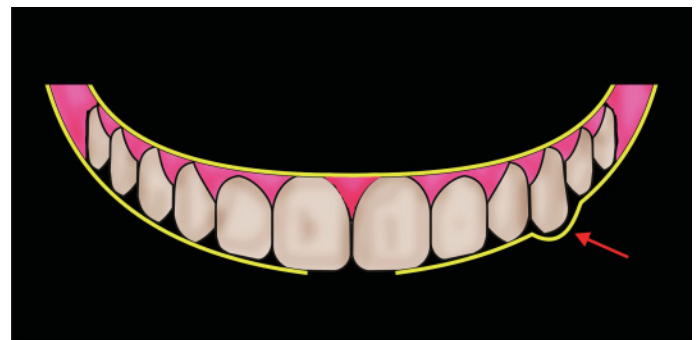


Figure 24.23 The abnormal morphology of the maxillary left first premolar has interrupted the gradation effect.

mid-third of the canine and premolars should be aligned parallel, as should those of the gingival thirds (Figure 24.22). Additionally, any poorly contoured or discoloured buccal restorations, discoloured teeth, incisal wear or gingival recession will interrupt this gradation effect (Figure 24.23).

- **Bucco-palatal inclination of the canine and premolar crowns:** The bucco-palatal inclination of the maxillary canine and premolar teeth should be correct and bilaterally symmetrical. Excessive palatal crown inclination will tend to hide the crown, whereas excessive buccal inclination will make the crown appear too prominent. Either way, the gradation effect is diminished.

- **Inclination of the maxillary occlusal plane:** In the sagittal plane, the maxillary occlusal plane has a posterosuperior orientation. Therefore, in frontal view there should be a gradual elevation of the maxillary occlusal plane as the dentition is followed posteriorly. Alterations to the sagittal cant of the maxillary occlusal plane may have a negative impact on the gradation effect.

Note

In complete denture prosthetics, the posterosuperior orientation of the maxillary occlusal plane is taken to be approximately parallel to the alar-tragal (Camper's) plane, which is approximately 8° to the Frankfort Horizontal plane. It is important to bear in mind that the orientation of Camper's plane and the Frankfort plane are subject to individual variability.

- **Maxillary arch form:** The arch form is an important determinant of the gradation effect. A square arch form or V-shaped arch may not provide the same visual effect as a gently curving ovoid arch form. The transition from the maxillary incisors to the gradation effect of the buccal segment begins at the **key tooth**, which is usually the maxillary canine, but may be the first premolar.

Gingival aesthetics

Gingival aesthetics are particularly important when the upper lip line is high and the gingival margins are clearly visible during smiling or even speech.

Gingival colour, texture and biotype

- **Gingival colour:** Healthy gingival tissue is pink in colour, though there is a degree of individual variability. There is also **ethnic variability**, with darker skinned individuals often exhibiting darker pigmentation of the attached gingival tissue (due to the increased level of activity of melanocytes in the stratified squamous epithelium), though this does not affect the free gingival margin or labial/buccal mucosa.¹⁸
- **Gingival texture:** In approximately 40% of individuals the gingival tissues exhibit an 'orange peel'-type appearance, described as **stippling**; this is due to attachment of the supra-crestal periodontal fibres to the above epithelium.²
- **Periodontal biotype:** The depth (i.e. thickness) of the gingival tissues may be classified as thin, average or thick, described as equivalent biotypes. Thin periodontal biotypes are potentially at greater risk of **gingival recession** with restorative dentistry or orthodontic expansion, whereas thick biotypes may be potentially more prone to periodontal pocket formation.

Gingival level

For ideal gingival aesthetics the gingival margin level of the maxillary lateral incisors should be slightly lower than that of the central incisors and canines; the level of the gingival margins



Figure 24.24 (A) The gingival margin level of the maxillary lateral incisors should be slightly lower than that of the central incisors and canines, which should be approximately equal. The lateral incisor gingival margin may be level with the central incisor and canine, but should *not* be at a higher level. (B) Gingival margin asymmetries.

of the maxillary central incisors and canines should be approximately equal (Figure 24.24).

Common clinical situations where gingival margin height discrepancies may arise are:

- **Overeruption of anterior teeth:** If the incisal edge of the maxillary incisor crown is excessively worn or fractured, the tooth may continue to erupt, thereby bringing the gingival margin with it. Overeruption of the maxillary central incisors often occurs in patients with Class II division 2 incisor relationships (Figure 24.25).
- **Dental ankylosis and non-eruption:** Obliteration of the periodontal ligament and penetration of alveolar bone onto the root cementum is termed dental ankylosis; it eliminates the potential for tooth eruption. In a growing individual, such non-eruption of a tooth results in localized vertical deficiency of the alveolar ridge and **infraocclusion** of the tooth, i.e. the tooth *appears* to 'submerge' below the level of the surrounding teeth, which are erupting normally. A significant gingival margin discrepancy may be evident clinically.



Figure 24.25 Overeruption of the maxillary incisor teeth results in gingival height discrepancies, as the gingival margins move with the erupting teeth.

- **Canine-lateral incisor substitution:** If maxillary lateral incisors are missing, one treatment option is space closure by approximation of the central incisors and canines. The canine gingival margin may be level with or too high in relation to the central incisor, and is often too high in relation to the first premolar (Figure 24.26).
- **Severe crowding and/or rotation:** In such situations there is often a disorderly arrangement of the gingival margin levels.
- **Delayed apical migration of the gingival margin:** Immaturity of the gingival margins may result in an excessively incisal gingival margin level, which may not migrate gingivally until late adolescence (see Figure 23.10).

Note

The root morphology, cementoenamel junction (CEJ) and the level of the alveolar crest determine the level of the gingival margin, in the absence of disease. The gingival margin level may be modified by **selective dental intrusion** or **extrusion** with orthodontic appliances and/or **gingivectomy** or **periodontal surgery**, which may require osseous recontouring. Orthodontic extrusion maintains the relationship between the gingival tissues and the cementoenamel junction, results in bone deposition and produces an increased width of attached gingivae. Animal studies suggest the amount of vertical gain achieved in the gingival level during extrusion will generally be approximately 80% of the distance that the tooth is extruded.³⁶ More data are required on the clinical effects of intrusion in humans. However, animal studies suggest that the gingivae move approximately 60% of the distance that the teeth are intruded and the gingivae also tend to bunch up, which may result in a shortening of crown height in the short term.³⁷ Stable occlusal contact is required to maintain an intruded tooth position successfully.



Figure 24.26 Canine-lateral incisor substitution: the maxillary canine has been extruded to correct its gingival margin position in relation to the adjacent central incisor and first premolar teeth, and the tip height has been reduced and smoothed.



Figure 24.27 The interdental papillae should fill the spaces apical to the contact areas of adjacent teeth, termed the gingival embrasures.

Gingival contour

Gingival embrasures

The **interdental papillae** should fill the spaces apical to the contact areas of adjacent teeth, termed the **gingival embrasures** (Figure 24.27). Lack of gingival tissue in this apical embrasure space, i.e. loss of the interdental papillae, may occur as a result of periodontal disease (Figure 24.28); alternatively, the spaces may become evident following orthodontic realignment of triangular incisor teeth and/or crowded, overlapping incisor teeth, particularly in adults (Figure 24.29). This results in the development of unattractive **dark/black interdental triangles**, which are particularly evident in patients with a high upper lip line. Their management is described below.

Gingival zenith

When examining the gingivae around individual teeth, the gingival margin of the mandibular incisors and maxillary lateral



Figure 24.28 Loss of the interdental papillae may occur as a result of periodontal disease.



Figure 24.29 Dark interdental triangles may become evident following orthodontic alignment of triangular incisor teeth. It is important that patients are warned of this *prior* to treatment.

incisors tends to exhibit a half circular contour. The maxillary central incisors and canines exhibit a slightly more elliptical gingival margin contour, with the **zenith** (most apical point of the gingival margin outline) located distal to the longitudinal axis of the tooth crown (Figure 24.30). In the maxillary lateral incisor region and mandibular incisor region the zenith point is located on the long axis of the clinical crown.

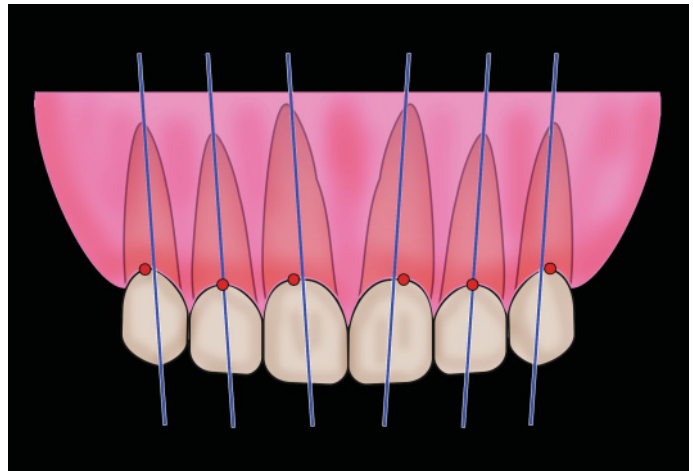


Figure 24.30 The gingival zenith points (shown in red) are the most apical points of the gingival margin outline. The zenith point should be coincident with the long axis of the maxillary lateral incisor crown and distal to the long axes of the maxillary central incisor and canine crowns.

Contacts, connectors and embrasures

The morphological pattern of the interdental embrasures, contacts and connectors has a significant influence on dental and smile aesthetics. The **incisal embrasures** are the triangular spaces between the edges of the teeth (Figure 24.31). Ideally the embrasure space between the maxillary central incisors, the central incisors and lateral incisors and the lateral incisors and canines progressively increases in size from the incisors distally. Awareness of this relationship is particularly important when restoring the incisal edges of anterior teeth.³⁸

The **connector** area may be defined as the zone in which two adjacent teeth *appear* to meet; the term was introduced by Morley and Eubank.³⁹ The ideal connector area between the maxillary central incisors is 50% of their clinical crown height, between the maxillary central incisor and lateral incisor is 40% of the clinical crown height of the central incisor, and between the lateral incisor and canine is 30% of the height of the central incisor crown. This is referred to as the **50:40:30 rule**. The **contact areas** between anterior teeth are smaller than the connectors and are the points where the teeth actually meet (Figure 24.32).

The triangular areas apical to the interdental connector areas are termed the **gingival embrasures**, which are ideally filled by the interdental papillae. Loss of the interdental papillae may occur as a result of periodontal disease, or iatrogenically (see below). Tarnow et al.⁴⁰ described the **5 mm rule**, which states that when the distance from the interdental contact point to the interproximal osseous crest is 5 mm or less, there is complete fill of the gingival embrasure with the interdental papilla. For every 1 mm above 5 mm, the chance of complete fill is progressively reduced by 50%.

Note

Between the maxillary central incisors, the 'ideal' aesthetic appearance results from 50% connector area and 50% papilla, termed the **50:50 rule** (Figure 24.33).⁴¹ Patients may present with pretreatment crowding in the maxillary labial segment, particularly with overlapping central incisors that are triangular in shape. In such patients, alignment of the maxillary labial segment often results in the appearance of dark triangles (see above) between the incisors due to incisal migration of the connector area and an excessive gingival location of the interdental papilla. Management of this situation requires interdental enamel reduction between the central incisor teeth and their subsequent orthodontic approximation. This effectively increases the height of the connector area, relocating the contact point in an apical direction and squeezes the interdental papilla incisally, resulting in improved aesthetics (Figure 24.34). It is important that the potential appearance of dark triangles is discussed with patients prior to treatment; otherwise their subsequent 'creation' during treatment may distress them.

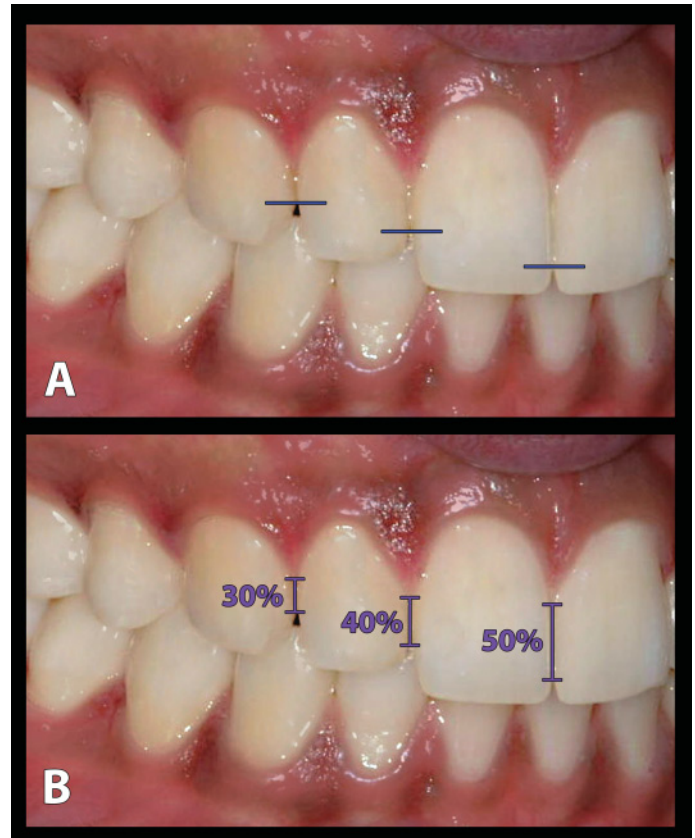


Figure 24.32 (A) The contact areas (or contact points) are the points where the teeth actually meet. Progressing from the incisors distally, their position progresses from incisal to cervical. (B) The connector area may be defined as the zone in which two adjacent teeth *appear* to meet. The ideal connector area between the maxillary central incisors is 50% of their clinical crown height, between the maxillary central incisor and lateral incisor is 40% of the clinical crown height of the central incisor, and between the lateral incisor and canine is 30% of the height of the central incisor crown. This is referred to as the 50:40:30 rule.



Figure 24.31 Incisal embrasures are the triangular spaces between the edges of the teeth, which ideally progressively increase in size from the incisors distally.



Figure 24.33 Between the maxillary central incisors, the 'ideal' aesthetic appearance results from 50% connector area (including the incisal embrasure space) and 50% papilla, termed the 50:50 rule.

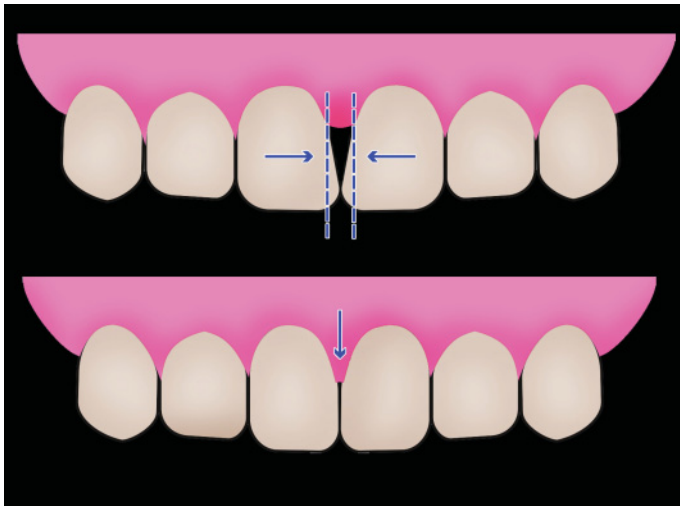


Figure 24.34 Alignment of the triangular maxillary incisors may result in the appearance of dark triangles due to incisal migration of the connector area and an excessive gingival location of the interdental papilla. Management of this situation requires interdental enamel reduction between the central incisor teeth and their subsequent orthodontic approximation, which increases the height of the connector area, relocating the contact point in an apical direction and squeezing the interdental papilla incisally.

Tooth colour

One of the most important aesthetic factors in the smile is the colour and 'brightness' of the teeth. Shade selection for dental restorations and tooth whitening procedures requires an understanding of colour science and a methodical approach to clinical diagnosis.

Description of tooth colour

Tooth colour has four primary attributes that permit its description. These are: hue, chroma, value and translucency. The first three attributes are described in the **Munsell colour notation**, a colour analysis system.⁴²

- **Hue:** May be defined as the *basic colour*, e.g. red, yellow, blue, etc.
- **Chroma:** Describes the *intensity* or saturation of the hue.
- **Value:** Describes the *brightness* or *darkness* of the hue.

In addition to these attributes, **translucency** describes the *appearance between complete opacity and complete transparency*. Highly opaque teeth or restorations tend to appear dull and 'lifeless'.

Arch shade progression

There is a progressive change in tooth shade from the central incisors posteriorly. The maxillary central incisors are the brightest, the lateral incisors are less bright and the canines are rela-

tively dark. The premolars are brighter than the canines, with progressive darkening towards the posterior molar teeth.

Tooth shade value contrast with skin colour

Facial skin colour and complexion should be a deciding factor in the determination of tooth colour, particularly tooth shade value, in dental aesthetic procedures. Recent research has demonstrated that variation in skin colour for a given tooth shade value influences perceived smile attractiveness (Figure 24.35).⁴³ The brightest tooth shade combined with dark skin was rated relatively unattractive in comparison to other skin shades. Darker teeth were rated as most unattractive when combined with fair skin. These findings may be explained by the optical illusion resulting from the greater *contrast between skin colour and tooth shade value*. The brightest tooth shade was not perceived the most attractive and not all skin colours were perceived equally attractive with bright, white teeth. Dark skinned patients requesting very bright, white teeth may be advised of the perceived unattractive and perhaps unnatural proposed appearance.⁴³

Age changes

Ageing affects all the structural components of the human body and tooth colour is no exception. The colour of teeth is due to the underlying dentine showing through the covering translucent enamel. In youth, teeth appear brighter and more translucent. Advancing age leads to the formation of secondary dentine and sclerosis of dentinal tubules, concomitant with a reduction in size of pulp chambers. Surface enamel becomes eroded and thinner. Thereby thicker and darker dentine shows through thinner and now less translucent enamel. Overall, the teeth become darker and less translucent.⁴⁴

Tooth colour has a strong correlation with age, generally becoming darker and more yellow with time.⁴⁵ After the age of approximately 35 years, teeth become darker, redder and more saturated except in the cervical region, which becomes more yellow.⁴⁶ Studies have shown women to have lighter and less yellow teeth than men.⁴⁵

Clinical shade selection

The perception of tooth shade depends on reflected light from the tooth or teeth entering the observer's eyes and reaching the retina at the back of each eye; electrical impulses are sent from the retina to the visual cortex at the posterior aspect of the brain for interpretation. Some subjectivity is thereby unavoidable. This makes a systematic approach to shade selection all the more important.

The patient's teeth must be clean and viewed at eye level. Shade comparison should be made in natural daylight where possible (e.g. by a window) and taken again under different lighting conditions within the dental surgery. Shade selection should be undertaken at the start of the visit as teeth have a tendency to dry over the course of an appointment, thereby increasing in value. The shade guide tab should be placed directly next to the tooth being matched, under the lip. This permits a similar background for both the teeth and the shade guide tab.⁴⁷ The

Image not available in the electronic edition

Figure 24.35 Variation in skin colour for a given tooth shade value influences perceived smile attractiveness (From Sabherwal RS, Gonzalez J, Naini FB. Assessing the influence of skin color and tooth shade value on perceived smile attractiveness. JADA 2009;140(6):696–705. © 2009 American Dental Association. All rights reserved. Reprinted by permission.)

cervical, middle and incisal regions of the tooth should be matched independently and any additional surface features noted, such as translucent incisal edges or even mild areas of hypomineralization.⁴⁸

The ability to visually process colour progressively diminishes as an object is observed; objects appear gradually less saturated, eventually appearing almost grey. In order to permit the eyes to adjust it is important for the clinician to look at a pale blue

surface, such as a wall painted pale blue or better still the sky, between the selections of different shades.

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